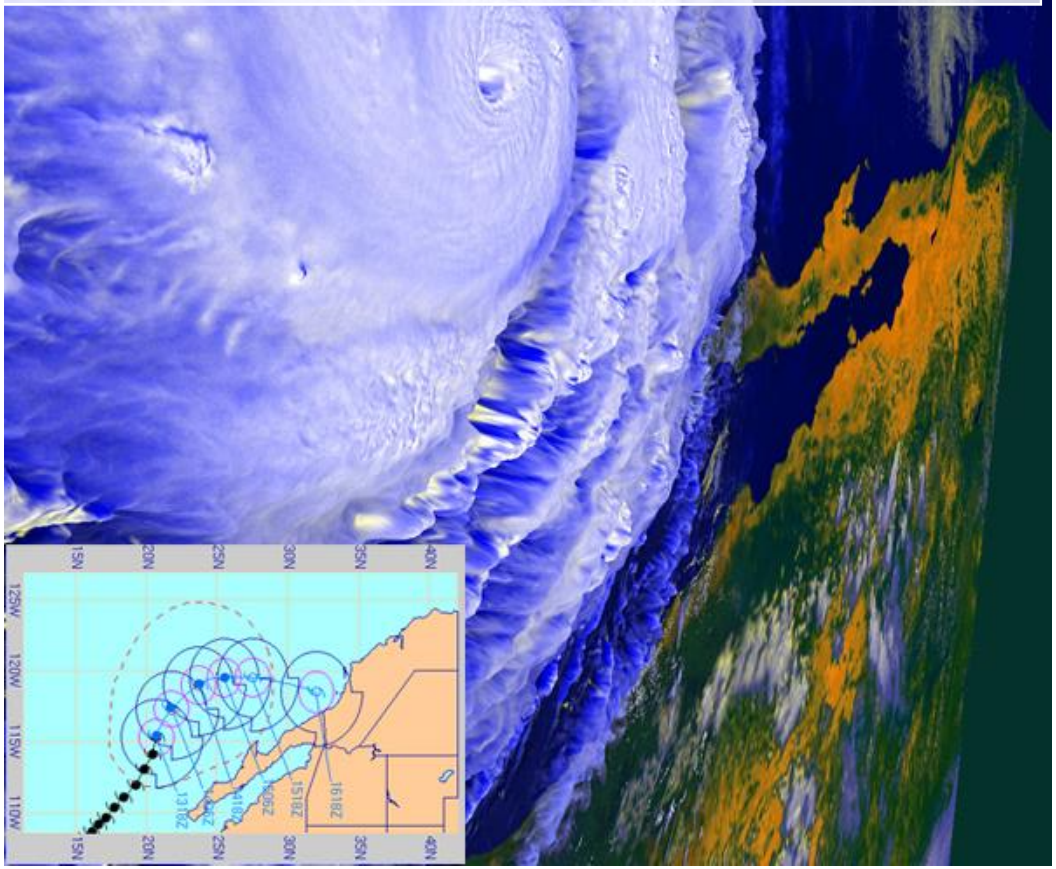
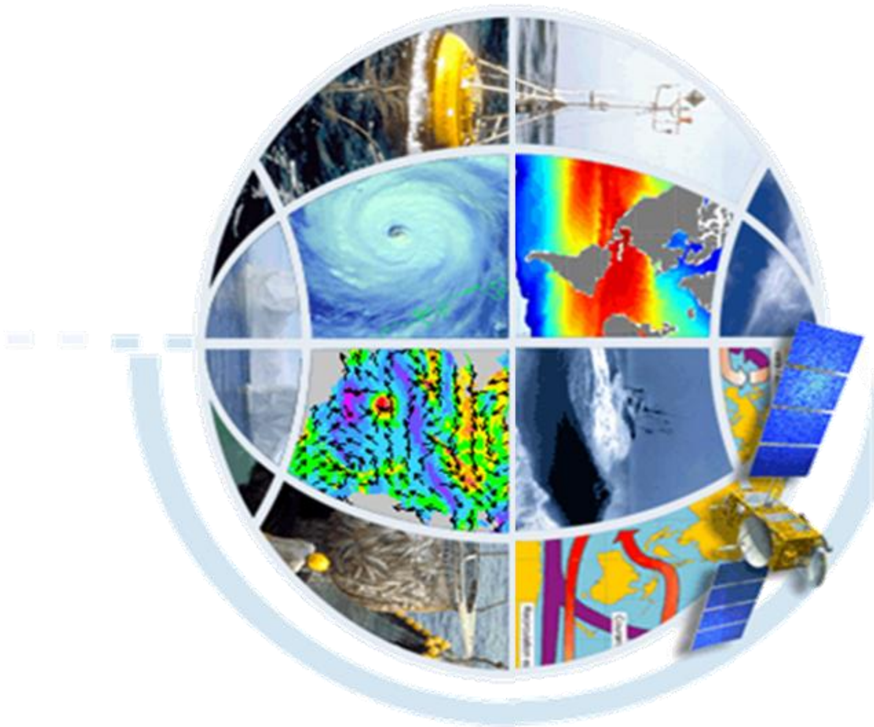
Marine Meteorology

For Masters And Mates

By: Captain H. Ebrahimi





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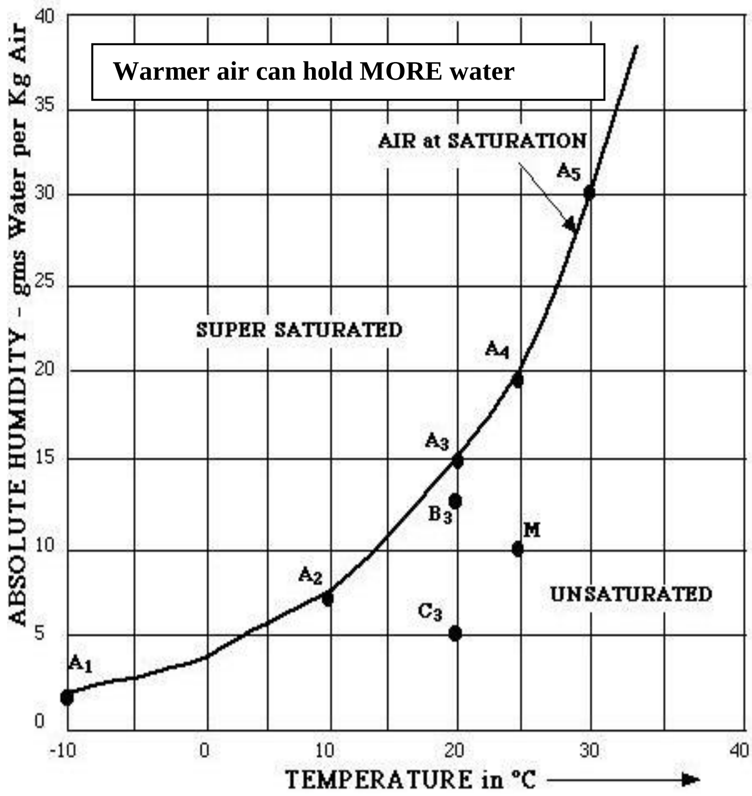
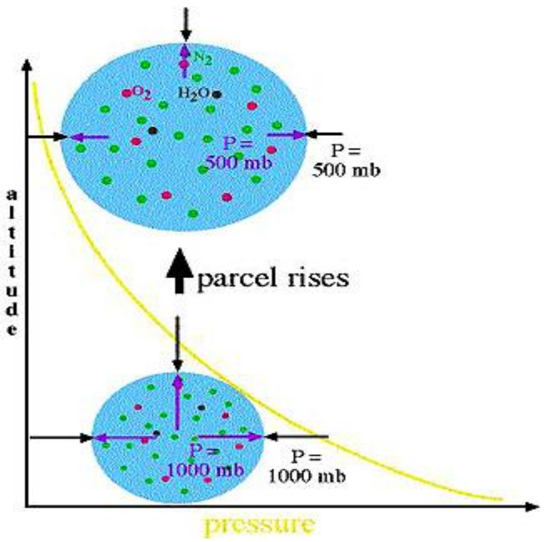
Stability of Air



1. The amount of water vapour in air is called humidity.
2. The amount of water vapour that can be held by air depends on the temperature.
3. The actual amount of vapour held in air is called absolute humidity ($\frac{gr}{kg}$).
4. Relative humidity: Relative humidity is the percentage ratio of the actual water vapour contained in a given sample of air, to the maximum quantity of water vapour that the sample can hold at that temperature.
5. Points A 1-5 are all at 100% relative humidity. B3 is 80%, C3 is 33%, M is 50%.
6. For air at temperature and humidity of B3, C3 and M to reach saturation (100% relative humidity) it must either ADD WATER VAPOUR OR BE COOLED

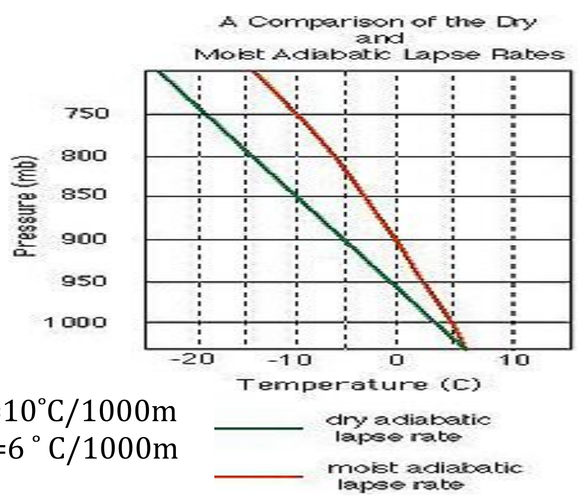


What happens when air is cooled?

1. Relative humidity increases.
2. Dew point is reached (100% relative humidity).
3. Water vapour (invisible) condenses to form water droplets (visible).
4. Sometimes the water vapour may change straight into solid state: called sublimation.

Adiabatic/ dry adiabatic lapse rate / moist adiabatic lapse rate

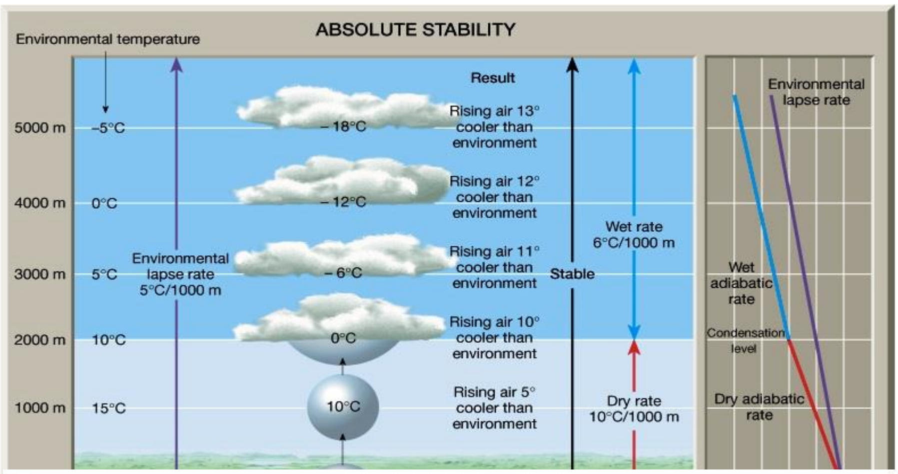
- When air is raised by going over a mountain it expands and cools. Warm air tends to move upward and cool until it meet a layer of warmer air. As it moves up, it expands, density and temperature decreases. This expansion is *adiabatic, meaning that there is essentially no* exchange of energy outside the air mass.
- The ***dry adiabatic lapse rate*** *is about* 10° C/km. Humid air will cool more slowly, as the release of latent heat from condensation partially counteracts the cooling. The *moist adiabatic lapse rate is* about 6° C/km.



DALR=10˚C/1000m
MALR=6 ˚ C/1000m

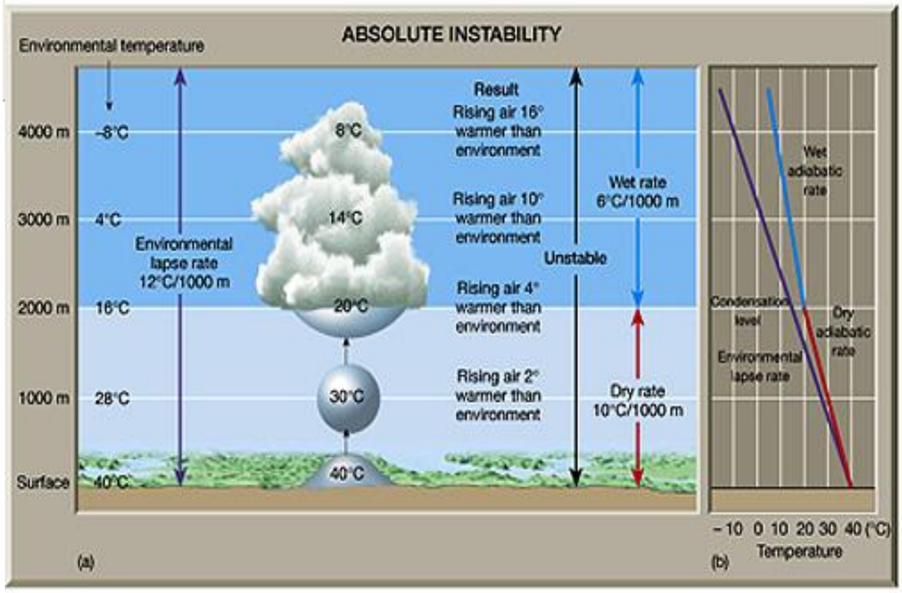
Absolute stability

- If the ELR is less than DALR and SALR then absolute stability exist.
- This means that the parcel of air is cooler (hence denser) than the surrounding air at that level and would thus try to return below to its original position. This happens regardless of whether the parcel was saturated or not.



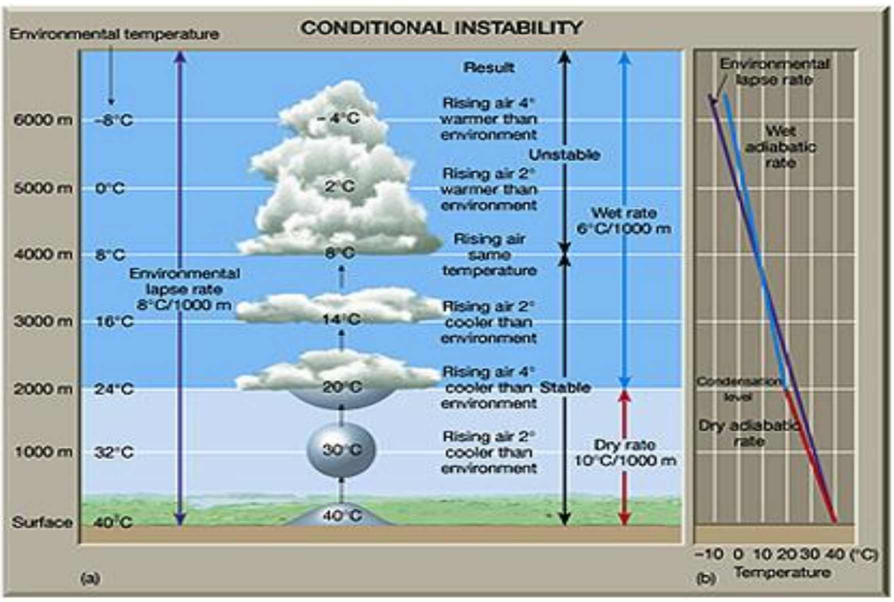
Absolute instability

- If the ELR is more than the DALR& SALR, then absolute instability exists.
- This means that the parcel of air is warmer than the surrounding air at the same level and would thus try to continue upwards in the direction of the original disturbance. This happens regardless of whether the parcel was originally saturated or not.



Conditional stability

- If the ELR is less then DALR but more than SALR.
- This means that if the parcel of air is dry, it is cooler (denser) than the surrounding air at the same level and would try to return below to its original position(stable equilibrium).
- If the parcel of air is saturated, it is warmer (less dense) than the surrounding air at the same level and would try to continue upwards(unstable equilibrium)



Neutral equilibrium of air

If the ELR coincides with DALR when the parcel of air is dry or with SALR when the parcel is saturated, then the parcel of air which is displaced upwards, is the same temperature as that of the surrounding air at the same level and would have no tendency to return to its original position or to continue upwards.

Stable Air

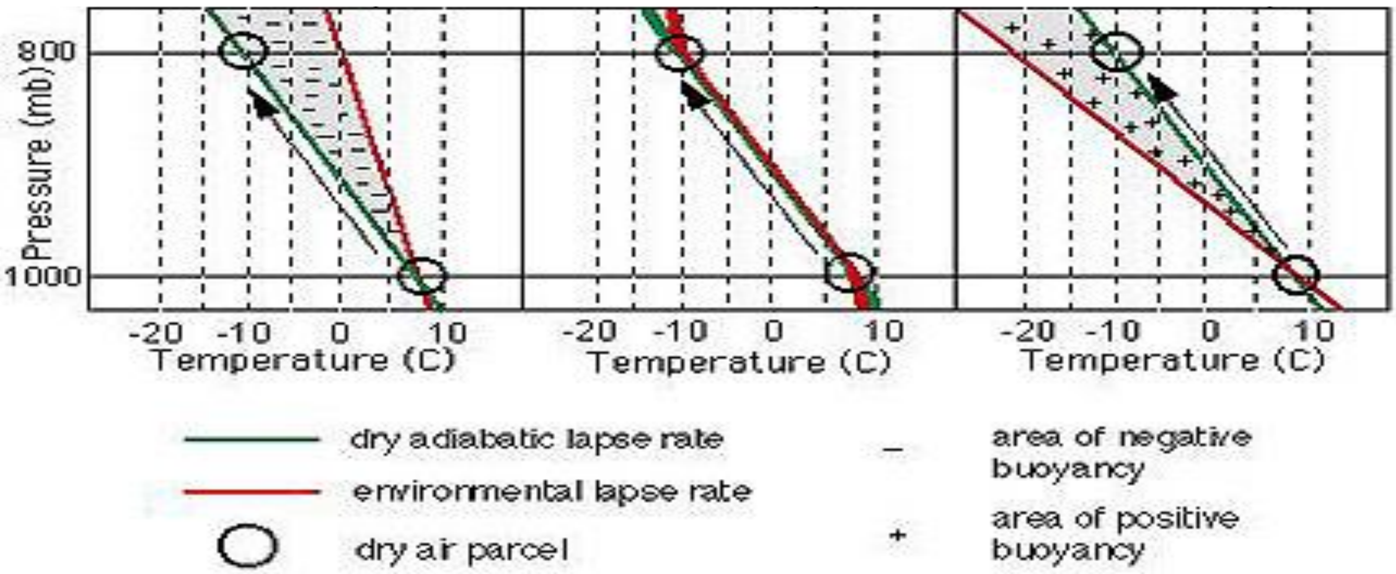
Defined by Slow Decrease or Increase of Temperature with Height

- Caused by Lack of Surface Warming or Surface Cooling
- Suppression of Rising Motions
- May Even Cause Sinking Motion

Unstable Air

Defined by Rapid Decrease of Temperature with Height

- Caused by Surface Becoming Much Warmer than Air
- Enhances Rising Motions
- Strong Heating of Surface Produces Rising Air



In each of these layers, we have lifted a dry parcel from an initial pressure of 1000 mb. The environmetal lapse rate has been altered in each case in order to illustrate the three categories of stability.

In the **stable** layer the parcel is colder than the surrounding air and wants to sink. It has negative buoyancy.

In the **neutral** layer the parcel has no buoyancy because it is always in equilibrium with the surrounding air. The pressure and temperature of the parcel is the same as the environment.

In the **unstable** layer the parcel cools more slowly than the lapse rate of the environment. The parcel is warmer than the surrounding air and wishes to continue rising due to its positive buoyancy.

A Stable Atmosphere is one that strongly resists change. It occurs whenever the Dry Adiabatic Lapse Rate is greater (and thus cools more with height) than the Environmental Lapse Rate. Air parcels under this condition that are forced upwards cool rapidly (quickly becoming colder than its surroundings) and act as though they have negative buoyancy, i.e., they overcome the lifting force and tend to sink at some stage to restore equilibrium. Stable air is clear (blue skies) and devoid of stormy conditions

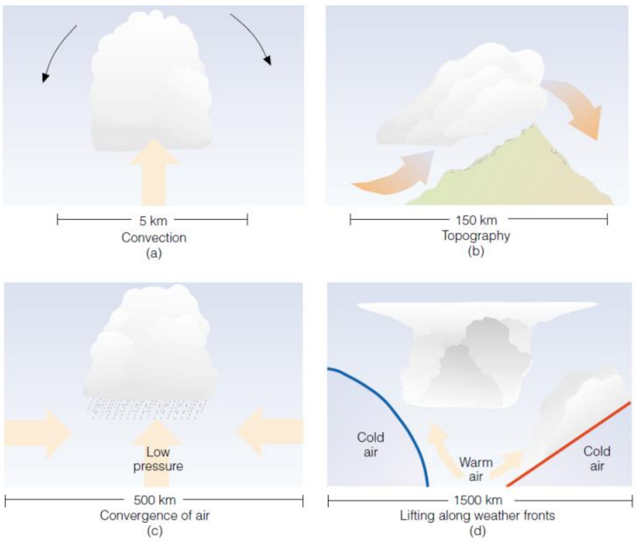
The lifting or rising of air can be accomplished in any of 4 ways:
1. Thermal Convection: from surface or lower atmosphere heating.

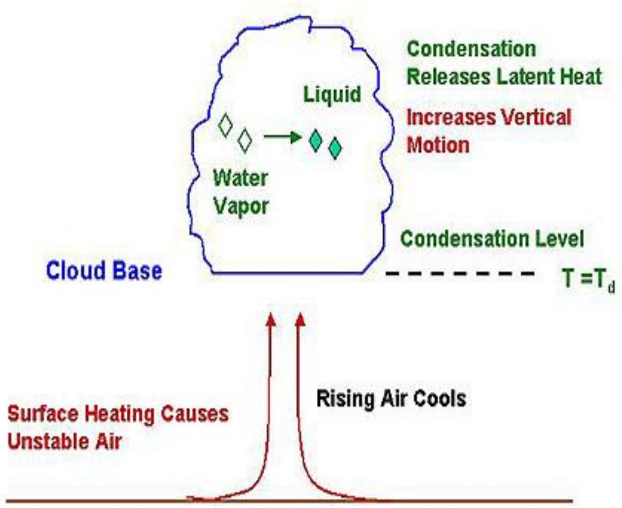
2. Dynamic Convergence: winds coming together force air to concentrate, squeezing it and causing it to move upwards.

3. Frontal Collision: two different air masses, one colder than the other, meet, causing the cold air to wedge under the warm air and driving the latter upward.

4. Orographic Uplift: Air moving laterally meets mountains or other features that form topographic barriers, causing the air to rise to get past

Clouds form through condensation mechanisms involving uplift of moist air



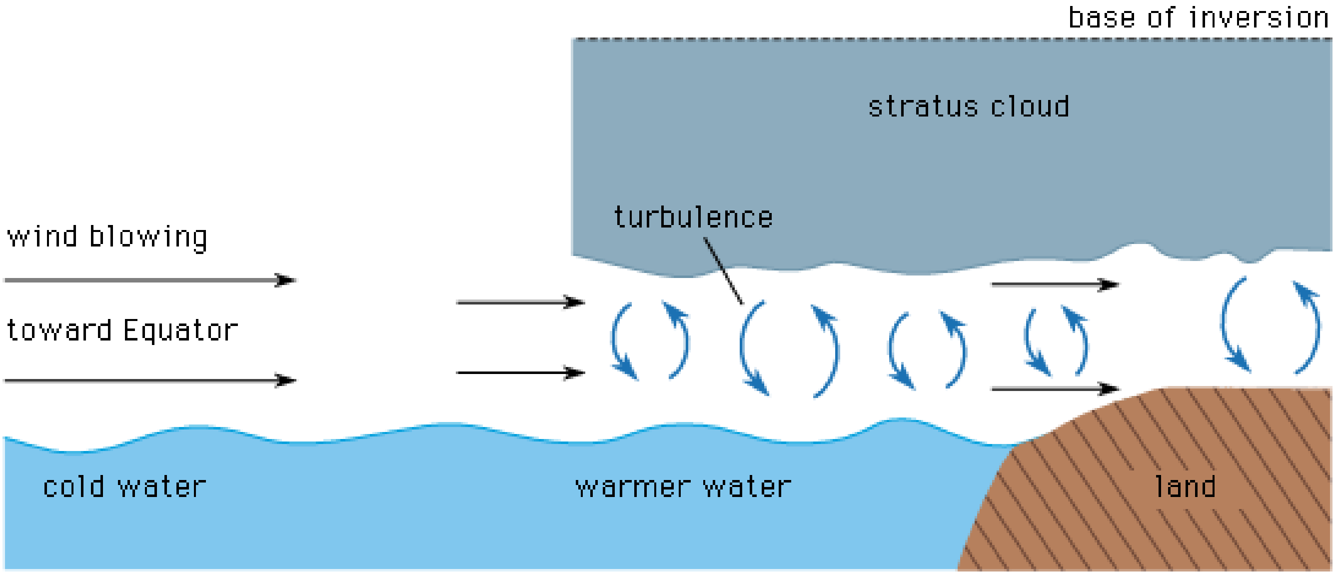


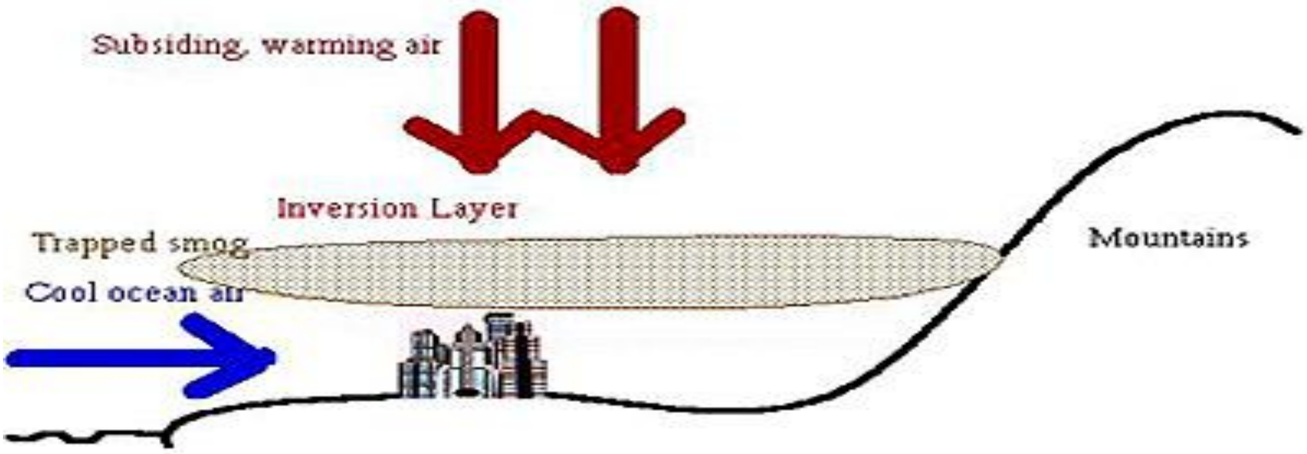
- **Inversion**: This occurs when condition reverse the lapse rate so that instead of continually falling temperatures a layer is reached in which the temperatures actually rise. This can happen naturally when a warm air mass rides over a cold.

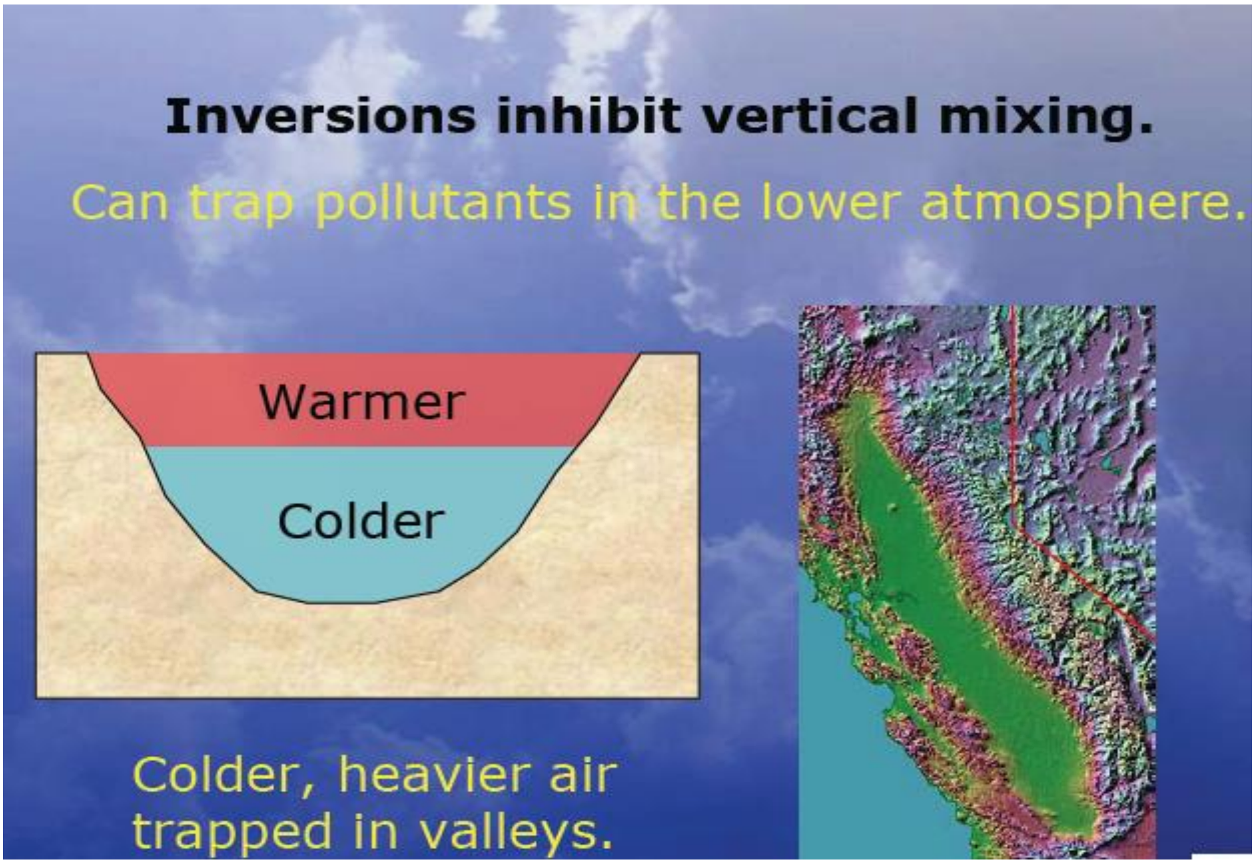
- If Air Is Hotter At High Altitude, Packets Of Rising Warm Air Are Stopped. This Is Called A ***Temperature Inversion***. Inversions Limit The Circulation Of Air, Causing Stagnation And Trapping Pollutants.

- ***Frontal Inversion:*** *When A Cold And Warm Front Meet, The Colder, More* Dense Air Moves Under The Warm Air, Forcing It Up And Creating An Inversion Layer.

- When Cold Air Moves Onto Land From The Ocean, Forcing The Warmer Air Upwards, And Creating An Inversion Layer. This Is Called ***Marine Inversion***.

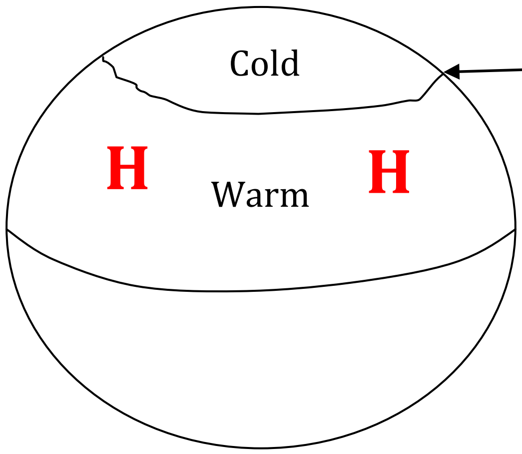

base of inversion
stratus cloud
turbulence
wind blowing
toward Equator
cold water
warmer water
land


Subsiding, warming air
Inversion Layer
Trapped smog
Cool ocean air
Mountains


Inversions inhibit vertical mixing.
Can trap pollutants in the lower atmosphere.
Warmer
Colder
Colder, heavier air
trapped in valleys.

Air Mass

- Larger volume of air that can move considerable horizontal distances within the troposphere is called air mass.
- The air masses have the same values of temperature and water vapor content at any one level over areas comprising thousands of square miles (at least 1600 km) or
- Large regions in which properties of air have small horizontal variation
- Air masses form in stable "source regions" such as in the sub tropics or near to the poles



Front: Battleground of Air Masses

- **Temperature Differences Concentrated**
- **Zone of Lower Pressure Where Lows (Storms) Often Form**

Air Mass Classification

A) An Absolute Classification Based on Principal Source Regions

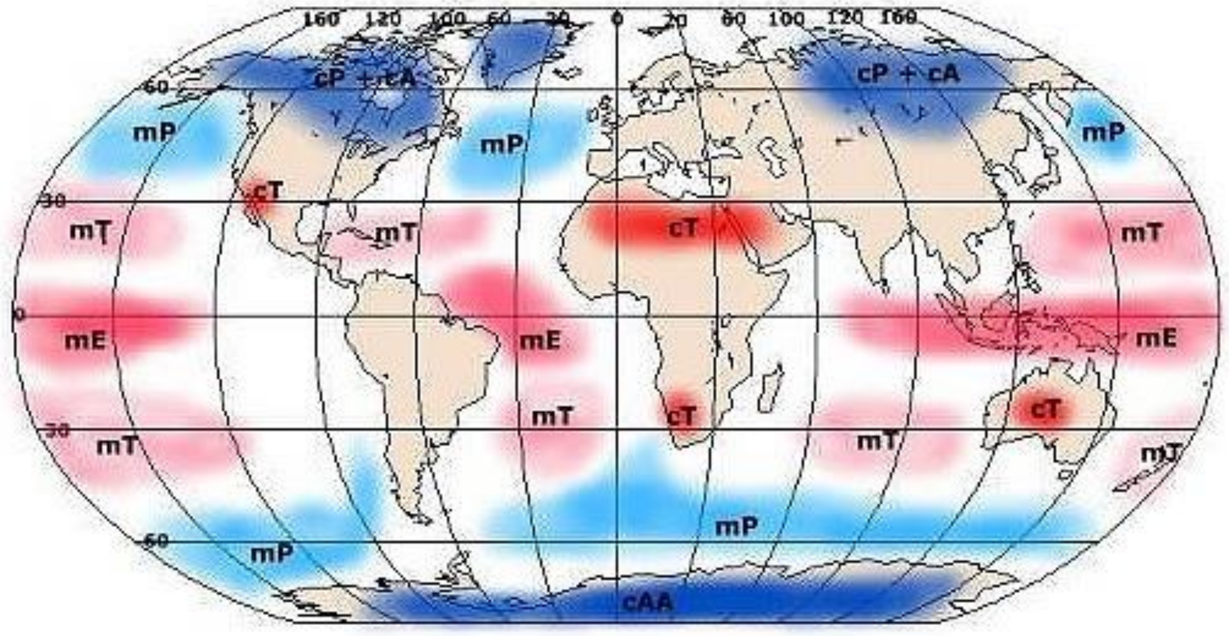
- **Tropical Maritime (Tm) – mild and moist**
- **Tropical Continental (Tc) – warm and dry**
- **Polar Maritime (Pm) – cool and moist**
- **Polar Continental (Pc) – cold and dry**
- **Arctic Maritime (Am) – cold and moist**

B) A Relative classification Based on the temperature of the air mass relative to the land or sea surface temperature in the area under consideration.

Cold air mass: Are those which Temperature near surface is less than the Temperature of underlying land or sea surface. (Thermally unstable, cumulus-type cloud, good visibility except in showers)

Warm air mass: Are those which Temperature near the surface is above the Temperature of the underlying land or sea surface (Thermally stable, stratified cloud and possibly fog)

Air Mass	Symbol	Characteristics/Comments
Continental Arctic	cA	Form exclusively in the Arctic and Antarctic regions and descend toward the equator. Bitterly cold and extremely dry in the winter, cool and dry during the summer.
Continental Polar	cP	Form over dry lands. Cold and dry during the winter, mild and dry during the summer.
Continental Tropical	cT	Form over deserts and plains. In the United States, a flow into the US out of Mexico often sends a cT air mass northward. Typically hot and dry during the summer and mild and dry during the winter.
Maritime Polar	mP	Marine type humidities with cool or cold weather. Typically provide for miserable, damp, gray days. Mild to cold and humid with low stratus clouds and precipitation is often the rule with Maritime Polar air masses.
Maritime Tropical	mT	Hot, humid, sticky weather. A good example of when mT air masses affect the United States is during the summer with the Bermuda High phenomena. A southerly flow of hot, humid, sticky weather is circulated northward into the US. Rarely will mT air masses affect the US during the witner.



Air Masses Affecting Europe:

- Polar Maritime Air from Northern Canada and the Arctic Ocean; North Westerly Air Type
- Arctic Maritime Air from Arctic Ocean; Northerly Type
- Returning Polar Maritime Air from Northern Canada via More Southern Seas; South Westerly Air Type
- Tropical Maritime Air from the High Pressure Area; South Westerly Air Type
- Tropical Continental Air from Sahara Sub-Tropical High Pressure Area; South or South Easterly Air Type
- Polar Continental Air from Siberia High Pressure Area (Winter); Easterly Air Type

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Age of Air Mass: The time which has elapsed since the air mass left the source region.

Life history of air mass

The **Thermo Dynamical** Processes Which Create Modification in The Airmass Include Heating And Cooling From Below And The Addition Or Removal of Water Vapor by Condensation or Evaporation. **Dynamical (Mechanical)** Processes Which Produce Modification Are Convection, Turbulence And Subsidence.

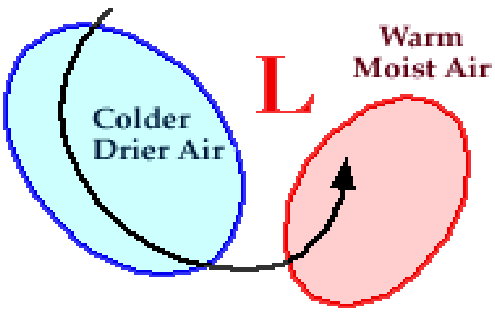
Heating from below produce a steep lapse rate of the temperature leading in to instability, convection and increased turbulence. Cumulus or cumulonimbus clouds with shower are common when sufficient moisture is available in the air mass or is added to the air mass by evaporation from the underlying surface. Strong convection generally results in good visibility, except in precipitation.

Cooling from below is most effective in the layers nearest to surface and extend upwards only slowly due to turbulence and convection is entirely suppressed by inversion of temperature which is produced soon in the lowest layers of an air mass under going cooling from below. In very light winds with little turbulence, the surface cooling of the air may be enough to cause condensation and fog.

Vertical movements induced by H/L pressure areas or topography may also affect the stability of an air mass. In case of an air mass drawn in to a low pressure, convergence and lifting dominate and air mass rendered un-stable. Subsidence associated with H.P acts to stabilize an air mass.

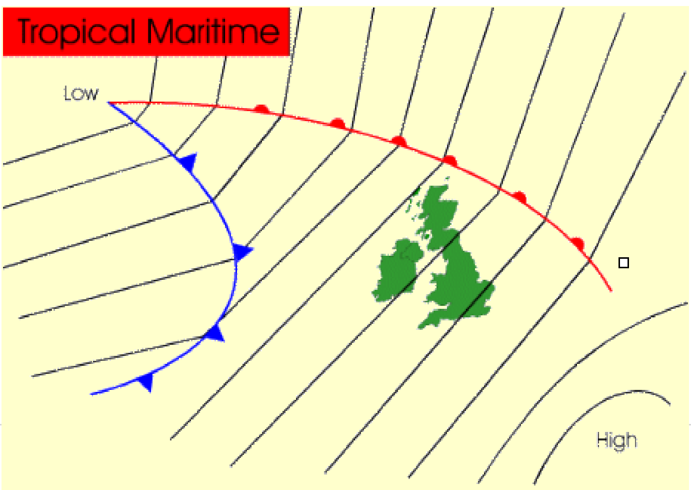
Lifting of an air mass over highlands, render it un-stable and descending on the leeward side make it more stable.

Movement of Air Mass:

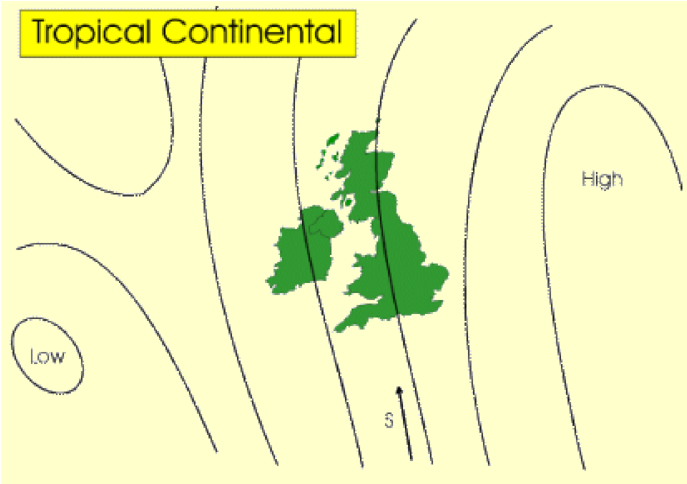


Air Mass Characteristics:

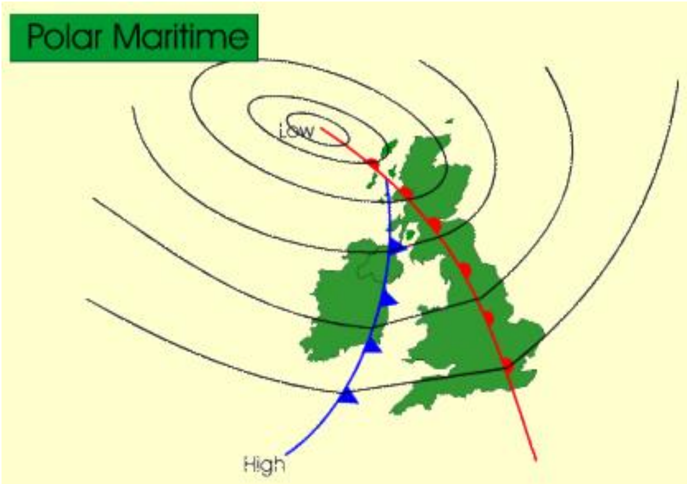
Tropical Maritime (Tm) air masses come from the south west and originate over the Azores or the Caribbean. They bring mild, damp, cloudy weather.



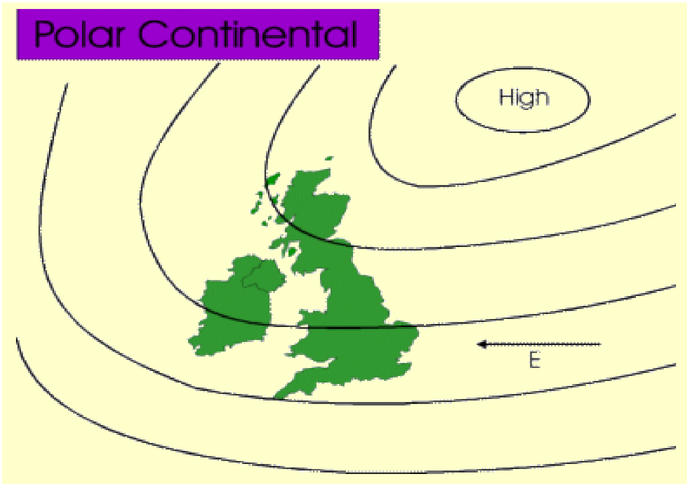
Tropical Continental (Tc) come from the south and originates over dry northern Africa. They bring hot, dry weather and summer heat waves.



Polar Maritime (Pm) come from the north-west and originate over the north Atlantic. They bring cool, moist conditions.

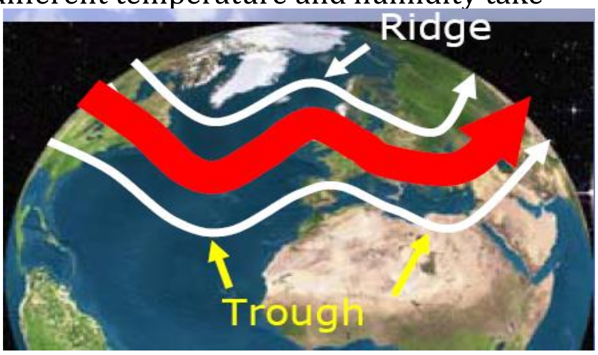


Polar Continental (Pc) come from the east and originates over Scandinavia and Russia. They bring clear dry conditions - cold in winter, warm in summer.



Air mass boundaries

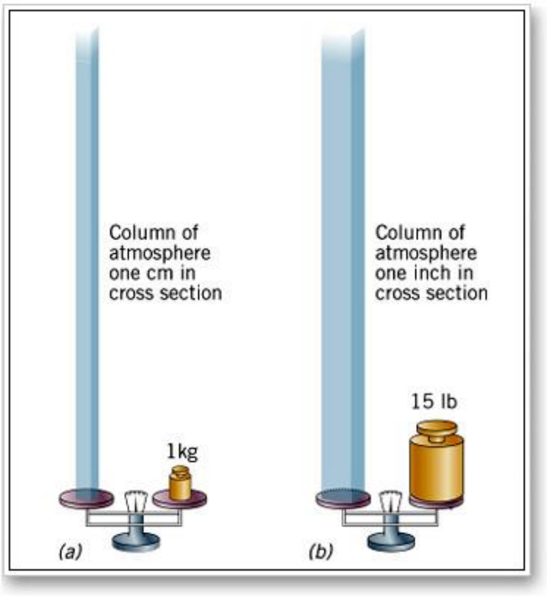
The boundary zones of two different air masses may be quite sharp due to mixing of air across the boundary between two distinct air masses having different temperature and humidity take place rather slowly.



The Winds and the Global Circulation System

Atmospheric Pressure

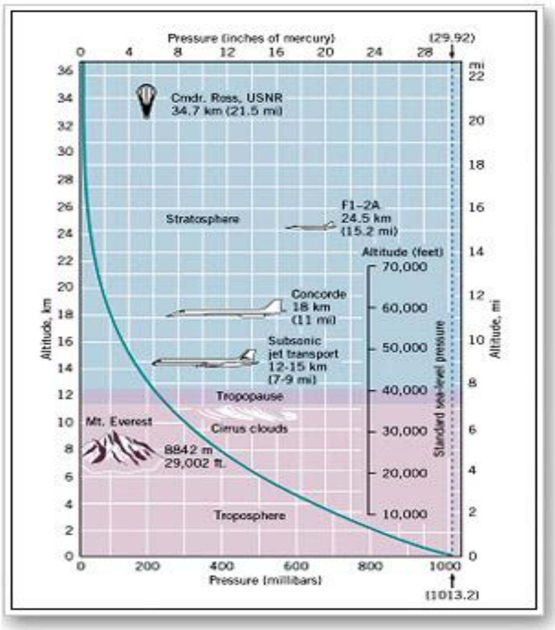
The Earth's land surface is actually located at the bottom of a vast ocean of air.
Like the water in the ocean, the air in the atmosphere is constantly pressing on the solid or liquid surface beneath it.
This figure depicts atmospheric pressure as the weight of a column of air.
(a) Metric system. The weight of a column of air 1 cm on a side is balanced by the weight of a mass of about 1kg.
(b) English system. The weight of a column of air 1 in. on a side is balanced by a weight of about 15 pounds.



Air Pressure Changes with Altitude

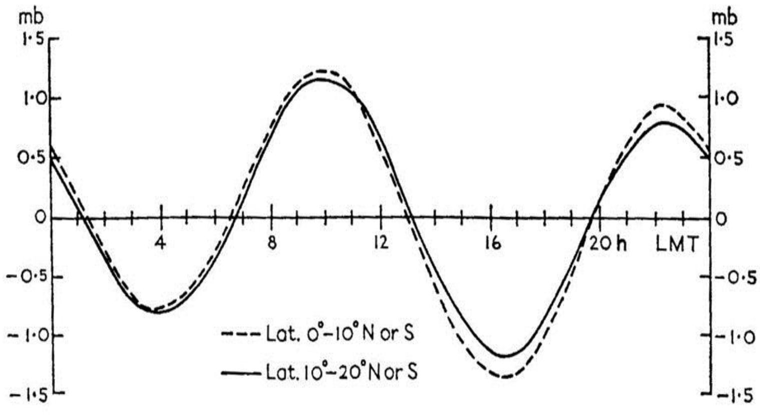
Because atmospheric pressure decreases rapidly with altitude near the surface, a small change in elevation will often produce a significant change in air pressure.

Atmospheric pressure decreases with increasing altitude above the Earth's surface.



Variation of pressure

(Semi – diurnal variation of pressure)
Pressure varies, twice daily, that is there are:
Two Maximal And Two Minimal of Pressure
Maximal occurs at 1000 and 2200 HRS and minimal at 0400 and 1600 HRS
Variation greater at the tropics than at temperate latitudes (2mb in tropics, 1mb at temperate latitudes
Values can be found in a meteorological atlas or in Pilot books

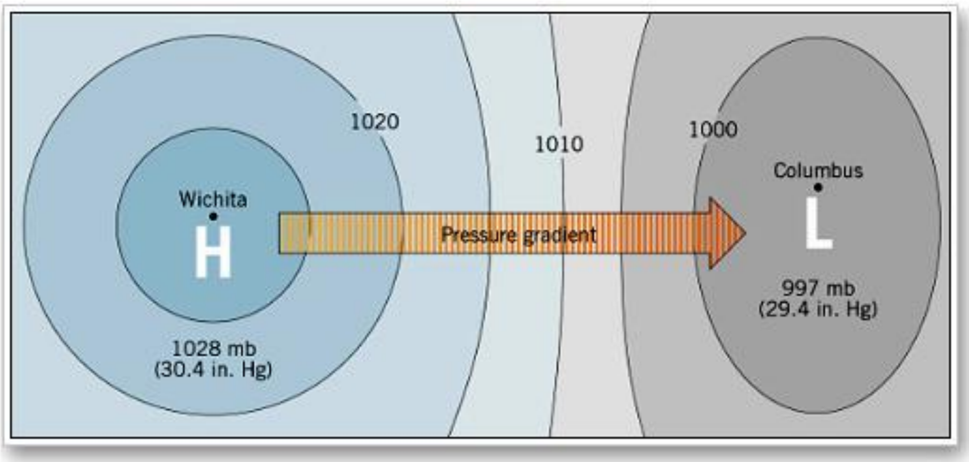


Mean diurnal variation of pressure

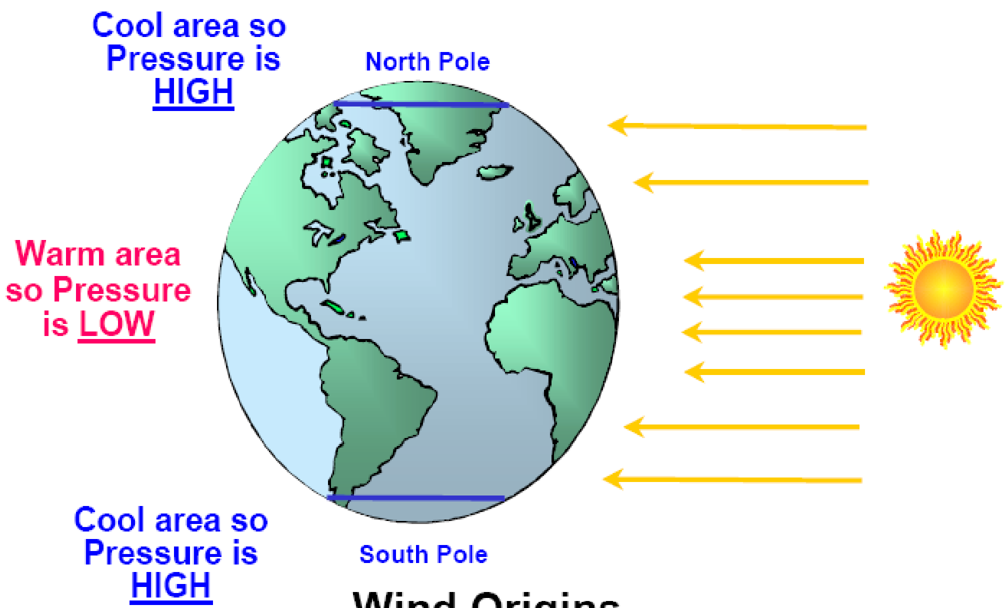
Wind

Wind is caused by differences in atmospheric pressure from place to place. Air tends to move from high to low pressure until the air pressures are equal.

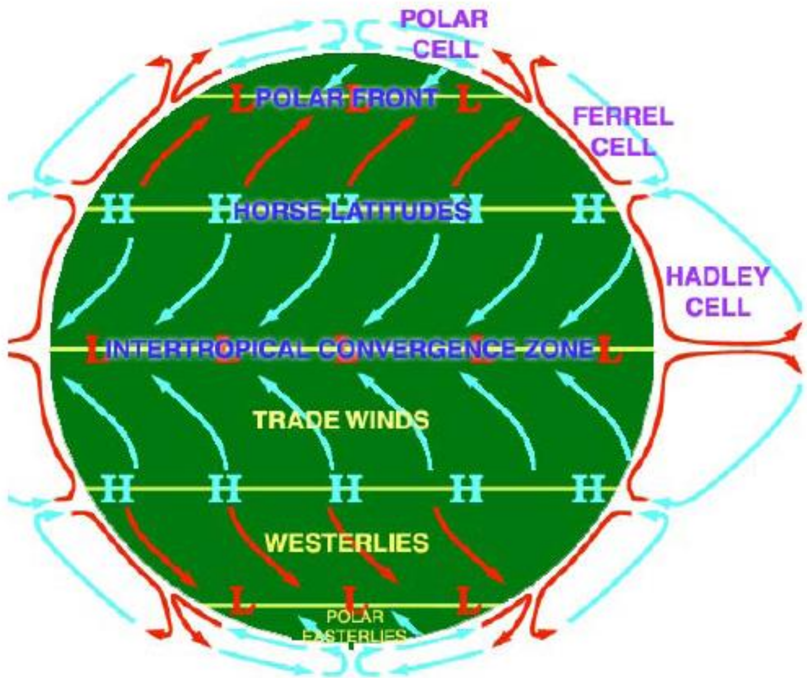
For example, pressure was higher over Wichita than Columbus, a pressure gradient force would push air from Wichita to Columbus.

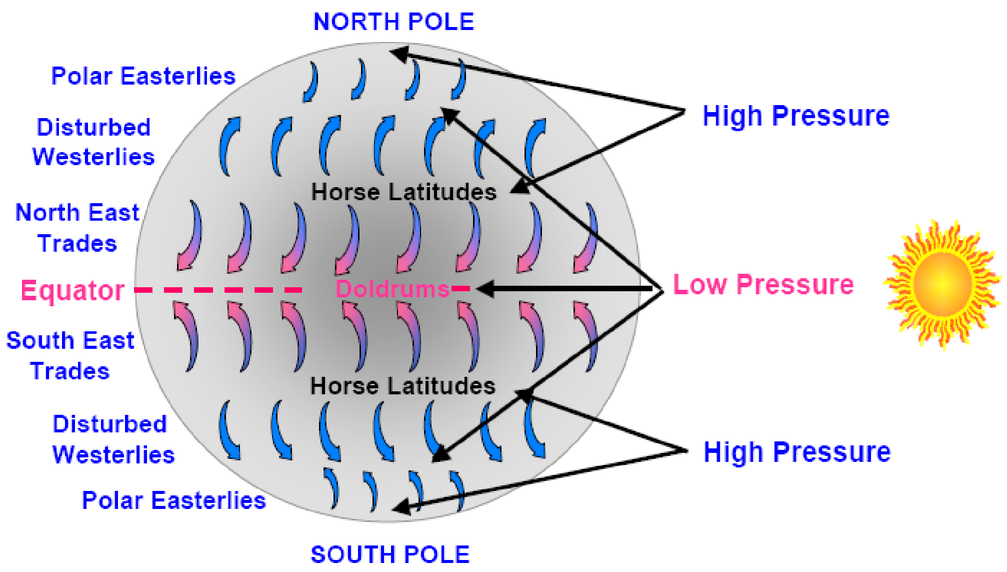


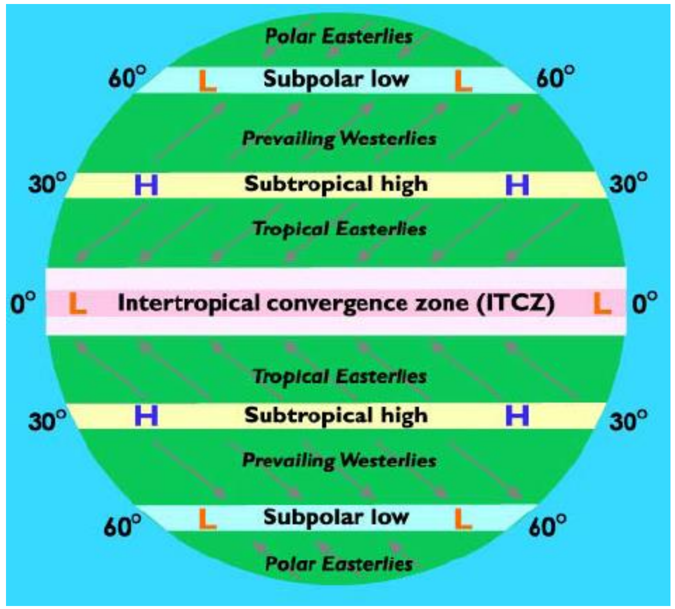
WORLD WIDE EFFECTS



Wind Origins

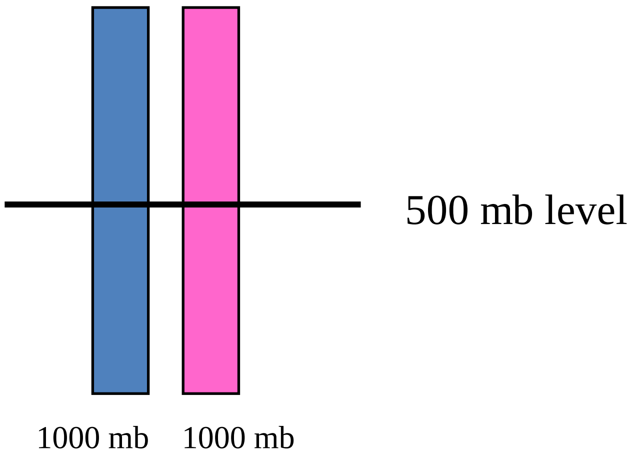


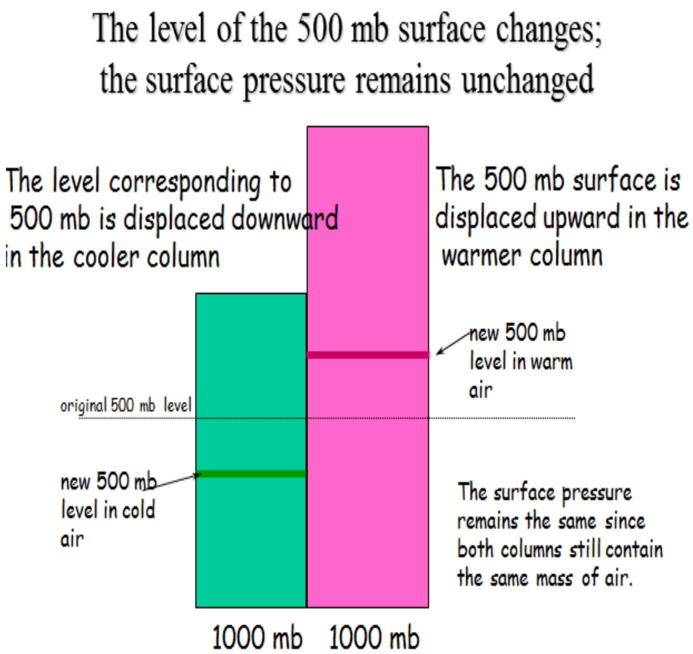


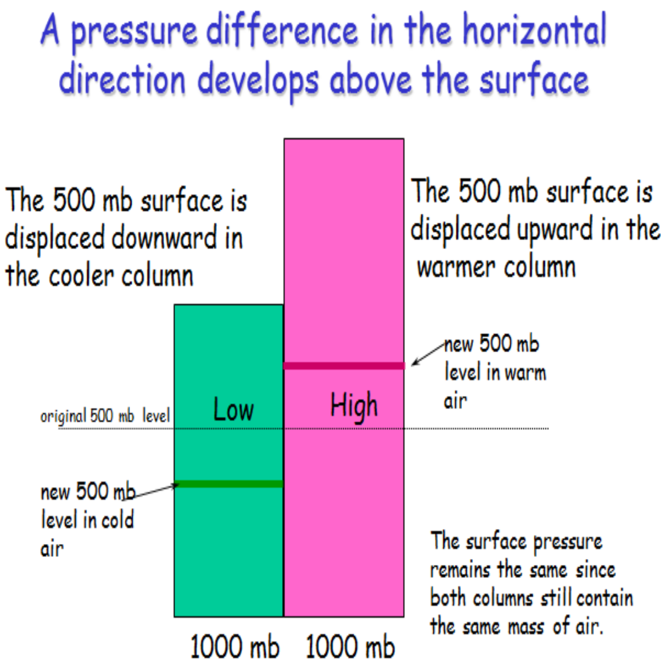


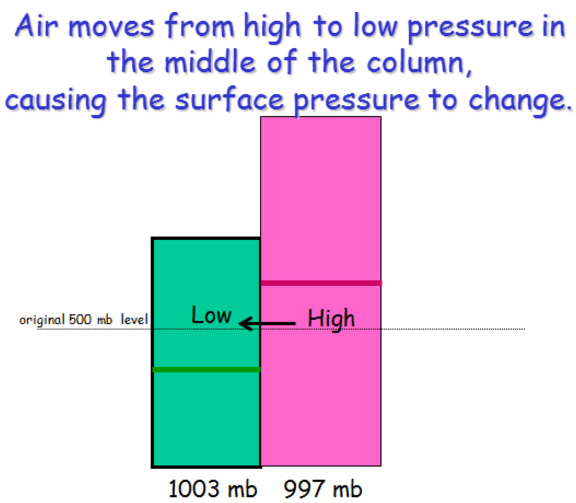
Thought Experiment:

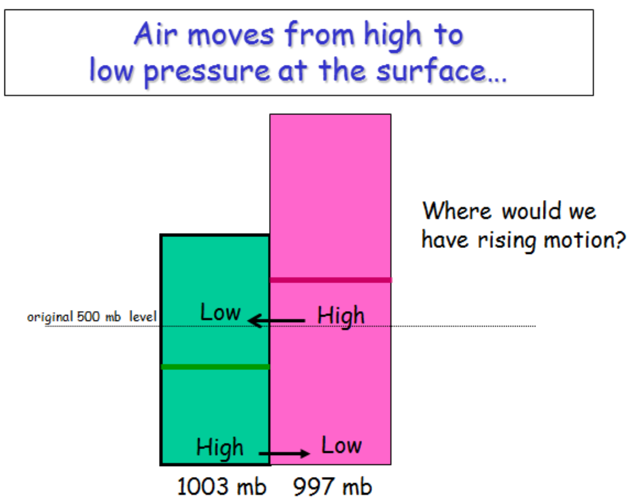
Consider two columns of air with the same temperature and distribution of mass





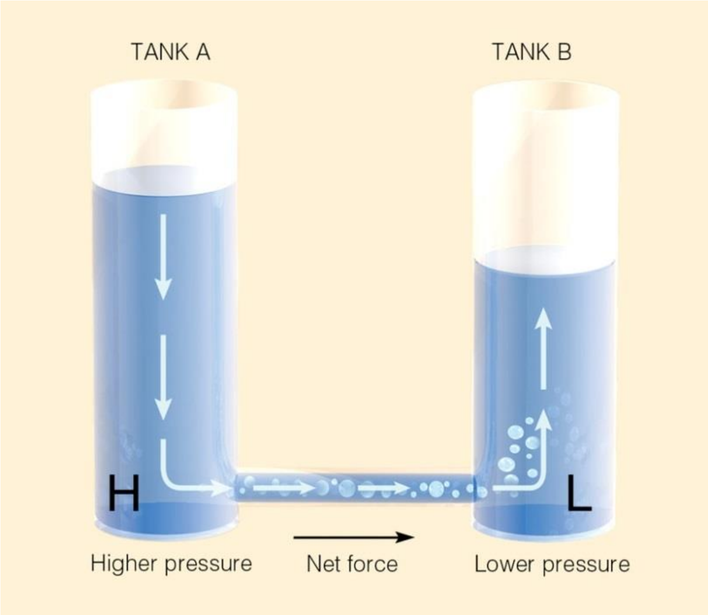




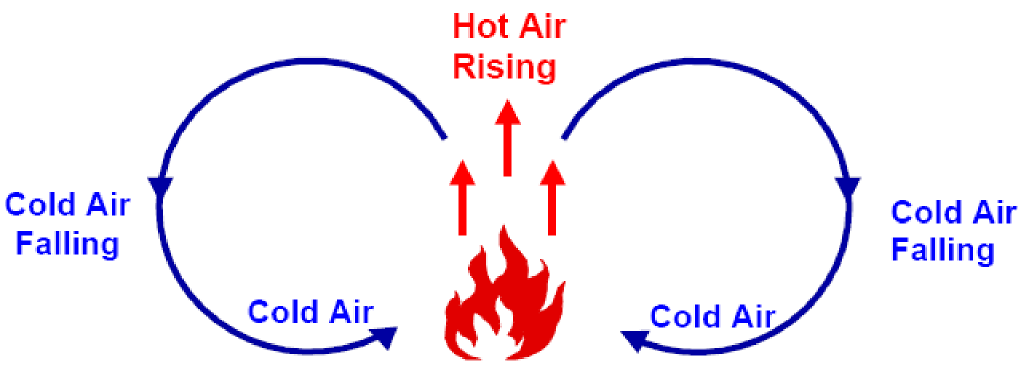


Thought Experiment Review

- Starting with a uniform atmosphere at rest, we introduced differential heating
- The differential heating caused different rates of expansion in the fluid
- The differing rates of expansion resulted in pressure differences aloft along a horizontal surface.
- The pressure differences then induced flow (wind!) in the fluid
- This is how the atmosphere converts differential heating into motion



Fundamental Cause of Weather



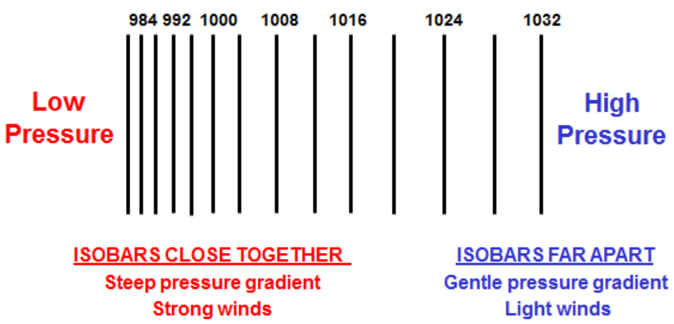
Horizontal Forces Affecting the Wind

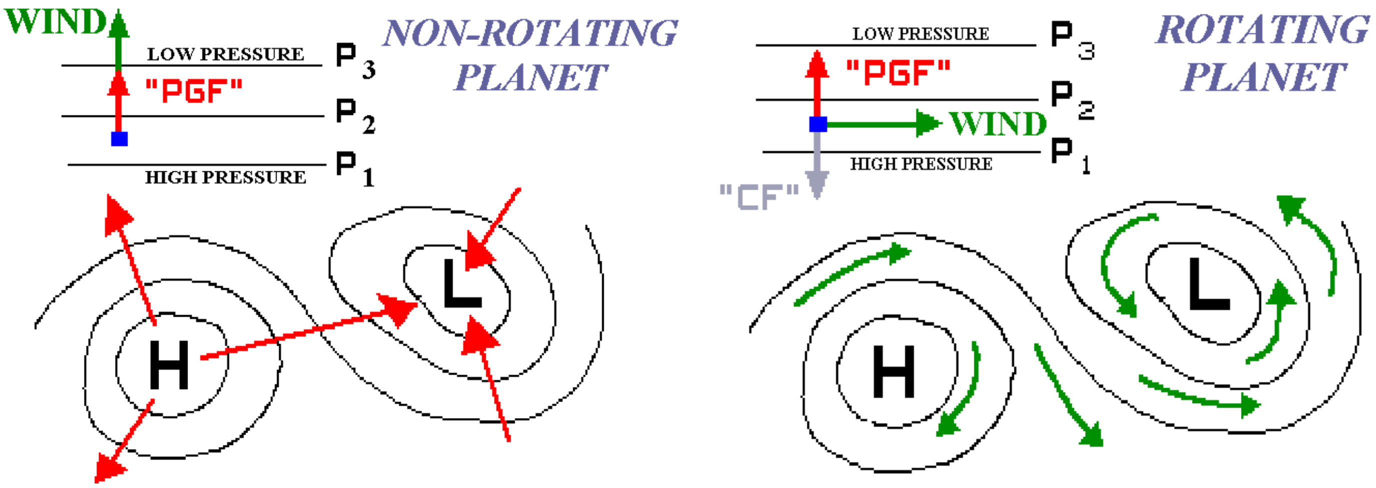
1-Pressure Gradient Force (PGF)
2-Friction (FF)
3-Coriolis (geostrophic) Force (CoF)
4-Centrifugal(cyclostrophic) Force (CeF)

1) Pressure-Gradient Force: *the force that generates wind, The force that generates winds results from horizontal pressure differences.*

Horizontal pressure gradient: The change of pressure over unit distance at right angle to the isobar which produce pressure gradient force, causing air to move from high to low pressure areas.

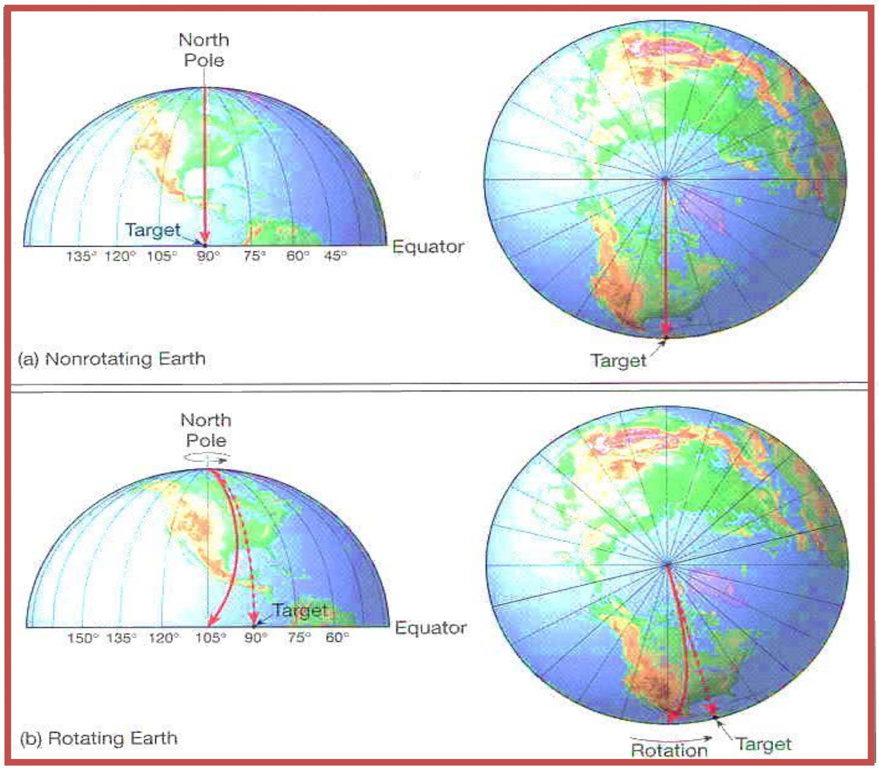
Isobars are lines connecting places of equal air pressure. The *spacing* of the isobars indicates the amount of pressure change occurring over a given distance.
Thus closely spaced isobars indicate steep pressure gradient and strong winds; widely spaced isobars indicate a weak pressure gradient and light winds.





The Coriolis Effect (G-G Coriolis – French Scientist 1835)

An object in motion on the Earth's surface always appears to be deflected away from its course. This effect is a result of the Earth's rotation, and is called the <u>Coriolis effect</u>.



The Coriolis effect illustrated using a 1-hour flight of a rocket traveling from the North Pole to a location on the equator. (a) On a nonrotating Earth, the rocket would travel straight to its target. (b) However, Earth rotates 15° each hour. Thus, although the rocket travels in a straight line, when we plot the path of the rocket on Earth's surface, it follows a curved path that veers to the right of the target.

CF=2wsinØV depends on: (w) angular velocity of earth, latitude (Ø), (v) geostrophic wind speed

At equator sin0˚=0 At pole sin90˚ =1

Acts to the right in NH and to the left in SH

Deflection is proportion to wind speed

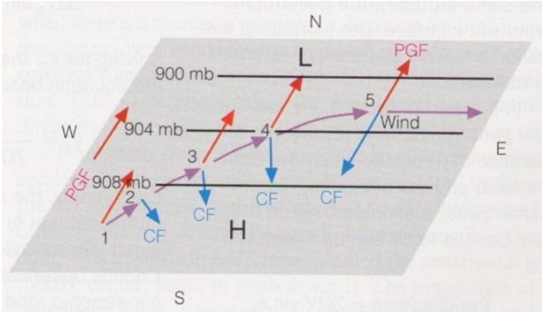
It is directed at right angles to the direction of air flow.

It affects only wind direction, not the wind speed.

In low latitudes the rate of change of the value of the force will be at a maximum for a given wind speed. As latitude increases the value of the force increases but its rate of change decreases.

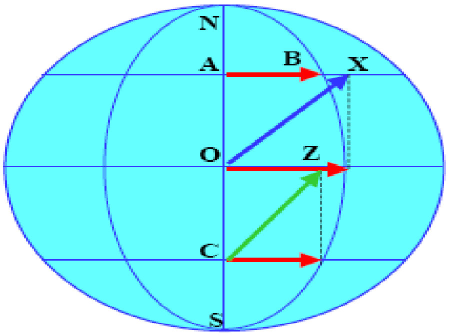
It also has the effect of deflecting ocean currents.

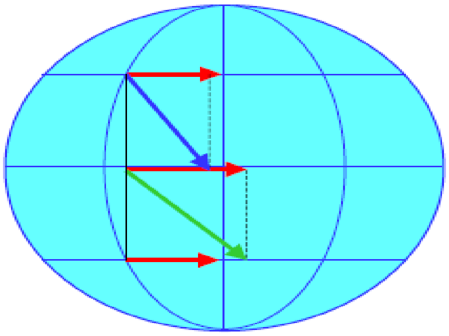
- **Coriolis Acts to Right in Northern Hemisphere**
- **Coriolis Deflection of Winds Blowing in Different Directions:**

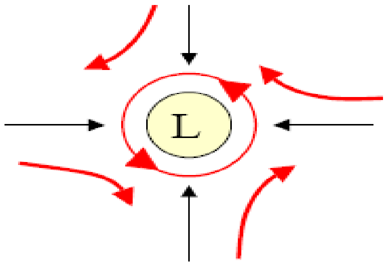


- **Northern Hemisphere:** All free-moving objects, including wind, are deflected to the *__right__ of their path of motion*.

- **Southern Hemisphere:** All free-moving objects, including wind, are deflected to the *__left__ of their path of motion*.







Wind attempts to blow towards the low pressure but is diverted to the right. (N Hemisphere)

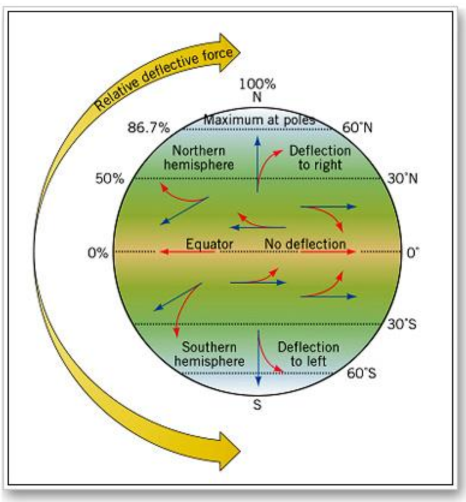
The earth makes one rotation per day, but the linear speed of a stationary object on the surface at the Equator is approximately 900 knots, while closer to the poles the speed of an object on the surface reduces eventually to zero.

If an object is propelled northwards from the equator, it is still also travelling east at 900 knots. It arrives at point X before a stationary object starting at A travelling east at a slower speed. It thus appears to be diverted to the RIGHT compared to A-B. This why an air mass which starts as a south wind will become a south west wind, and depressions rotate anticlockwise.

In the southern hemisphere, the north bound object starting at C arrives at Z after a stationary object starting at O. It thus appears to be diverted to the LEFT. Thus depressions in the S hemisphere rotate clockwise.

The right hand diagram shows a similar effect for objects travelling south.

Coriolis affects wind and tides; a north bound current will be deflected to the right in the N hemisphere.



Coriolis effect direction and strength. The Coriolis effect acts to deflect the paths of winds or ocean currents to the right in the northern hemisphere and to the left in the southern hemisphere as viewed from the starting point.

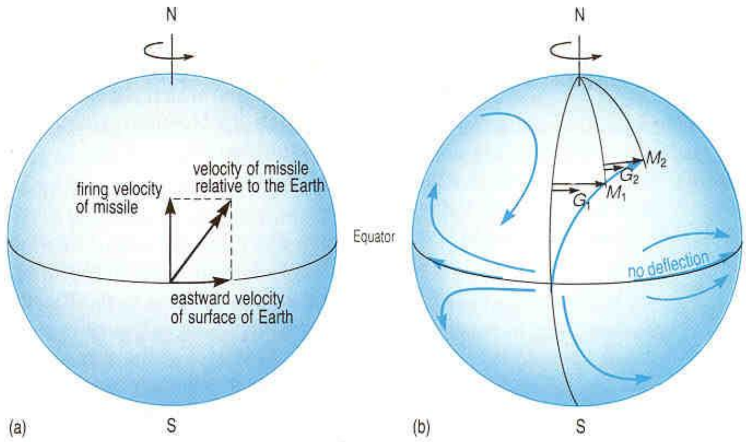


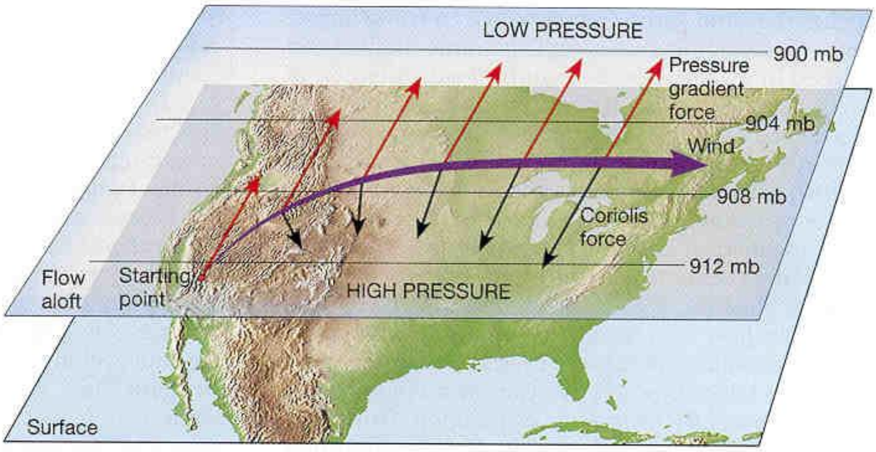
Figure 1.2 (a) A missile launched from the Equator has not only its northward firing velocity but also the same eastward velocity as the surface of the Earth at the Equator. The resultant velocity of the missile is therefore a combination of these two, as shown by the double arrow.

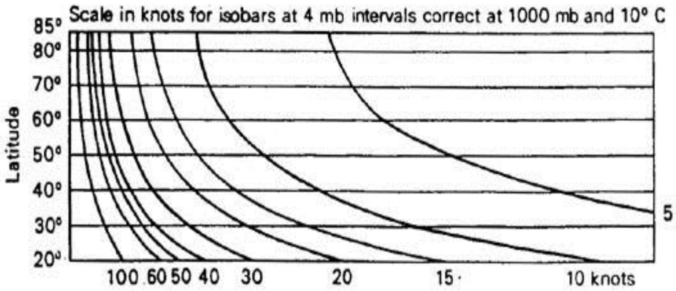
(b) The path taken by the missile in relation to the surface of the Earth. In time interval T_1, the missile has moved eastwards to M_1 and the Earth to G_1; in time interval T_2, the missile has moved to M_2 and the Earth to G_2. Note that the apparent deflection attributed to the Coriolis force (the difference between M_1 and G_1 and M_2 and G_2) increases with increasing latitude. The other blue curves show likely paths for missiles or any other bodies moving over the surface of the Earth without being strongly bound to it by friction.

Geostrophic Wind

- Balance between PGF and Coriolis force when isobars are straight and parallel
- Above the surface (above 1km)
- Wind blows parallel to isobars
- A few kilometers above the surface the effect of friction is negligible, and thus the Coriolis force is responsible for balancing the pressure-gradient force and thereby directing airflow.
- To illustrate, consider an air parcel initially at rest at 'Starting point' in Fig LT 6-13. Since our parcel is at rest, the Coriolis force acting on it is zero; only the pressure-gradient force acts on it. Under the influence of the pressure-gradient force, which is always directed perpendicularly to the isobars, the parcel begins to accelerate directly toward the area of low pressure. As soon as the flow begins, the Coriolis force starts to act and causes a deflection to the right of the path of motion (since our parcel is in the Northern Hemisphere). As the parcel continues to accelerate, the Coriolis force intensifies. Thus, the increased speed results in further deflection. Eventually the wind turns so that it is flowing parallel to the isobars. When this occurs the pressure-gradient force and Coriolis force balance and the airflow is said to be in geostrophic balance. Winds generated by this balance are called geostrophic winds.

Figure 6–13 The geostrophic wind. If Earth did not rotate, upper-level winds would flow directly from areas of higher pressure to areas of lower pressure. However, upper air winds are deflected by the Coriolis force until a balance has been reached between the Coriolis force and the pressure-gradient force. Above 600 meters, where friction is negligible, winds flow nearly parallel to the isobars and are called geostrophic winds.





- ✓ **Geostrophic Wind Scale**
- ✓ **Curved Flow and the Gradient Wind**

- Gradient wind is the horizontal air motion parallel to isobars which are curved and is due to the action of the PG, geostrophic and cyclostophic forces.
- Fig LT 6-15a shows the gradient flow around a centre of low pressure. As soon as the flow begins, the Coriolis force causes the air to be deflected. In the Northern Hemisphere the resulting wind blows counter clockwise about a low.

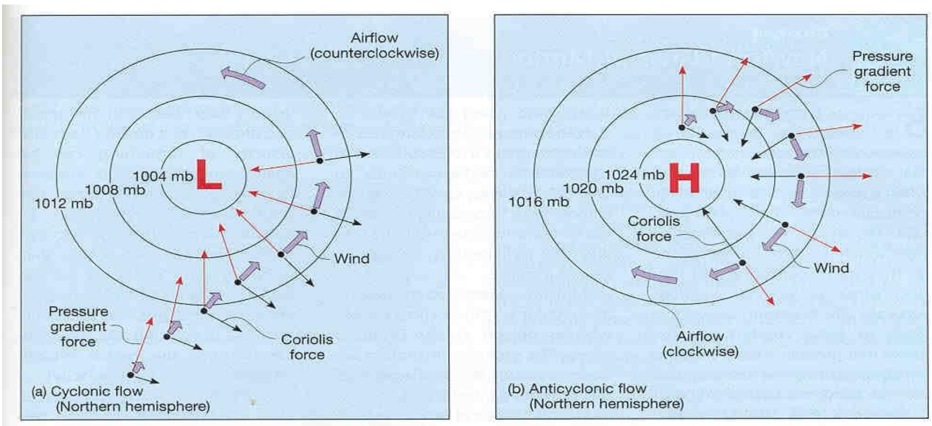
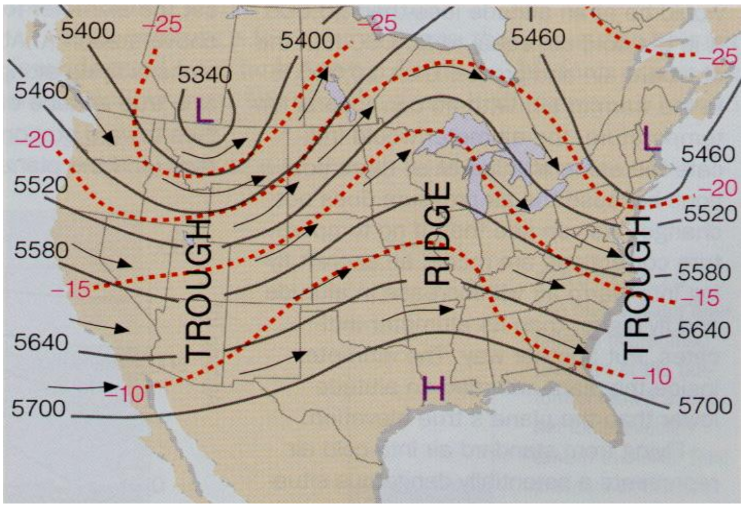


Figure 6–15 Idealized illustration showing expected airflow aloft around low- and high-pressure centers.

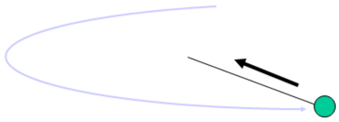
Pressure Patterns and Winds Aloft

At upper levels, winds blow parallel to the pressure/height contours



Centripetal Force

- Tie a weight to some string and spin it around your head
- The tension you maintain on the rope pulls the weight around in a circle
- Inward force - centripetal

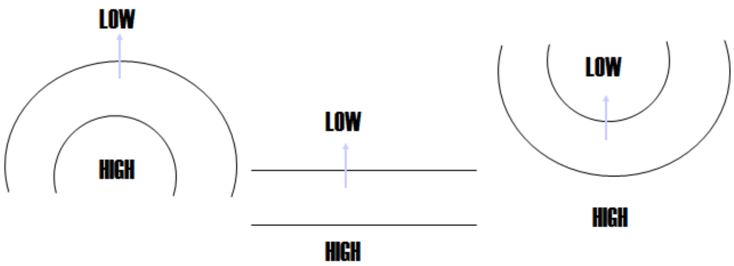


Centrifugal Force

- e.g. Fairground ride
- Centrifugal or cyclostrophic force acts radially outwards from the center of rotation of an air particle following a curved path and its value is proportional to gradient wind speed.
- Body thrown out against side

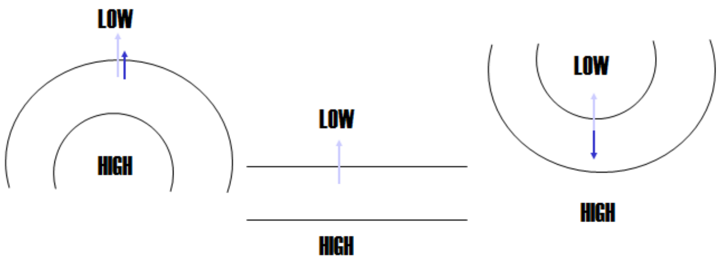
Pressure Gradient Force

Identical pressure gradient in each case



Centrifugal Force

Force needed for curved motion as viewed from above….



Magnitude

✓ Depends upon the radius of curvature of the curved path taken by the air parcel
✓ Depends upon the speed of the air parcel

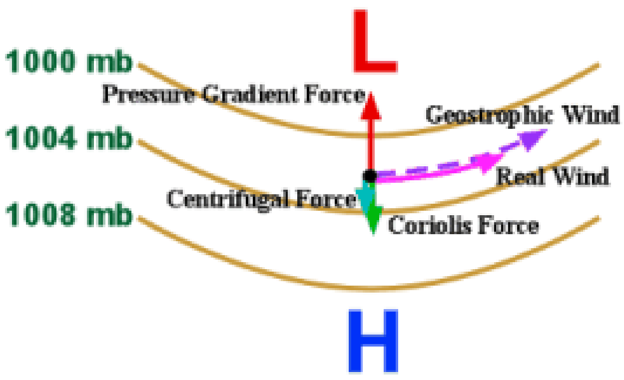
Direction

✓ At right angles to the direction of movement

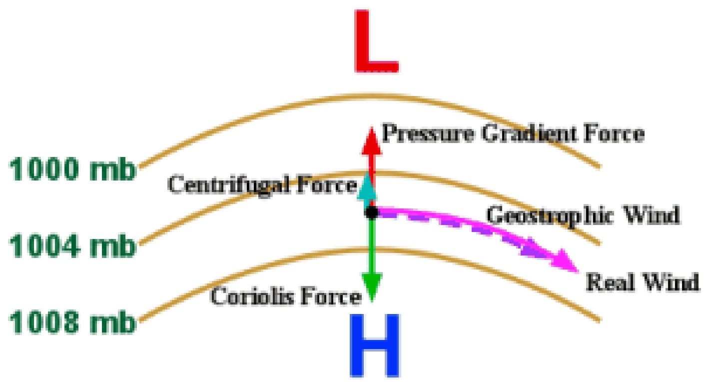
Gradient Wind Balance

The "Gradient Wind" is flow around a curved path where there are three forces involved in the balance:
1. Pressure Gradient Force
2. Coriolis Force
3. Centrifugal Force

Important in regions of strong curvature (near high or low pressure centers)



- Near a ridge, wind speeds up as centrifugal force opposes



- Near a trough, wind slows as centrifugal force adds to Coriolis

Friction is Important Near Earth's Surface

Frictional drag of the ground slows wind down

Magnitude
- ✓ Depends upon the speed of the air parcel
- ✓ Depends upon the roughness of the terrain
- ✓ Depends on the strength of turbulent coupling to surface

Direction
- ✓ Always acts in the direction
  exactly opposite to the movement of the air parcel

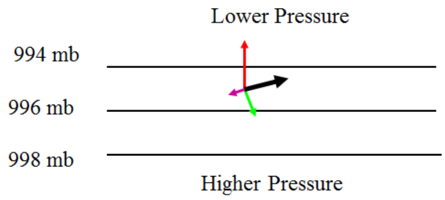
Important in the turbulent *friction layer*
- ✓ ~lowest 1-2 km of the atmosphere

Three-Way Balance Near Surface (Pressure + Coriolis + Friction)

- Friction can only slow wind speed, not change wind direction
- Near the surface, the wind speed is decreased by friction, so the Coriolis force is weaker does not quite balance the pressure gradient force

Force imbalance (PGF > CF) pulls wind in toward low pressure
Angle at which wind crosses isobars depends on turbulence and surface roughness (angle of indraft)
Average ~ 30 degrees on land and 10 at sea

Geostrophic Wind Plus Friction



Wind doesn't blow parallel to the isobars, but is deflected toward lower pressure; this happens close to the ground where terrain and vegetation provide friction

Surface Winds

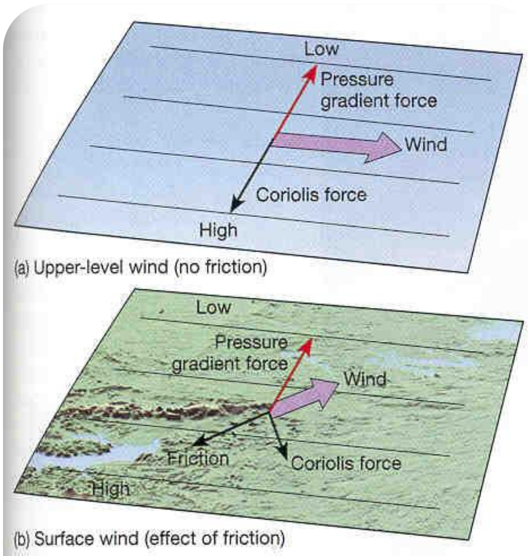


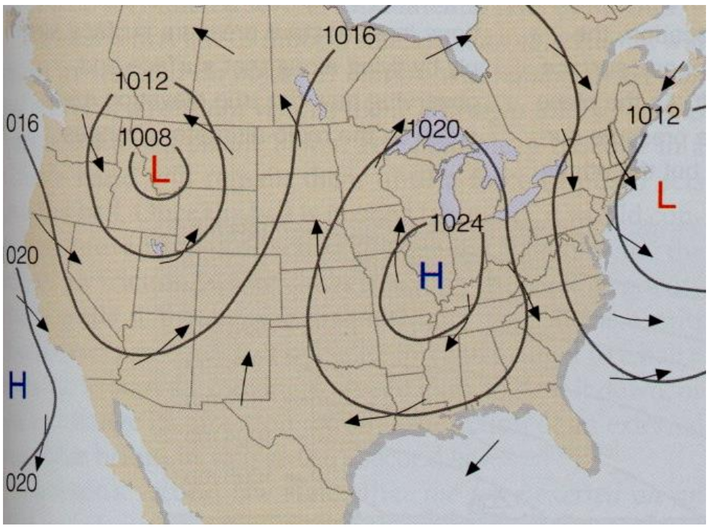
Figure 6–16 Comparison between upper-level winds and surface winds showing the effect of friction on airflow. Friction slows surface wind speed, which weakens the Coriolis force, causing the winds to cross the isobars.

- Friction has an important effect on wind only within the first few kilometers of Earth's surface.
- Friction acts to slow the movement of air. By slowing air movement, friction also reduces the Coriolis force, which is proportional to wind speed. This alters the force balance in favor of the pressure-gradient force with the outcome that there is a movement of air at an angle across the isobars toward the area of lower pressure.
- In a cyclone pressure decreases inward. Thus friction causes a net flow toward its centre. Therefore, the resultant winds blow into and counterclockwise about a surface cyclone.
- In an anticyclone the oppose is true: the pressure decreases outward and thus friction causes a net flow away from the centre. Therefore, the resultant winds blow outward and clockwise about a surface anticyclone.
- In whatever hemisphere, friction causes a net inflow (convergence) around a cyclone and a net outflow (divergence) around an anticyclone.

Surface Pressure Patterns and Winds

Near the surface in the Northern Hemisphere, winds blow

- counterclockwise around and in toward the center of low pressure areas
- clockwise around and outward from the center of high pressure areas



Converging Wind, Vertical Motion, and Weather

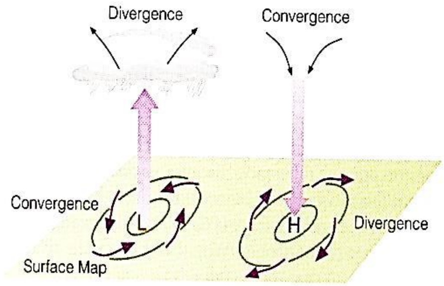


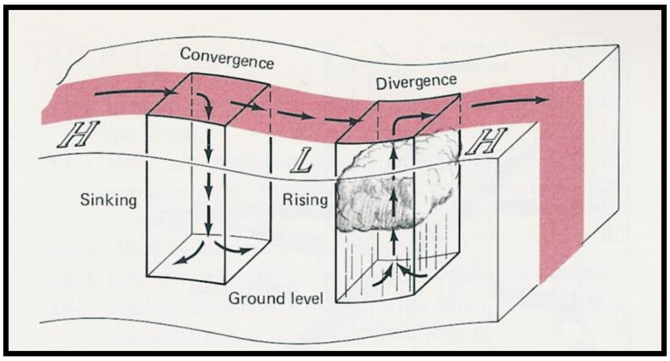
FIGURE 9.32
Winds and air motions associated with surface highs and lows in the Northern Hemisphere.

Surface winds blow
- In toward center of low pressure (convergence)
- Out from center of high pressure (divergence)

Air moves vertically to compensate for surface convergence or divergence
- Surface convergence leads to divergence aloft
- Surface divergence leads to convergence aloft

Vertical Motion

Mass Conservation leads to upward motion beneath regions of divergence downward motion beneath regions of convergence



How Winds Generate Vertical Air Flow

- First consider the situation around a surface low pressure system (cyclone) in which the air is spiraling inward. Here the net inward transport of air causes a shrinking of the area occupied by the air mass, a process called horizontal convergence. Whenever air converges horizontally, it must pile up. That is, it must increase in height to allow for the decreased area it now occupies.
- This process generates a "taller" and therefore heavier air column. Thus low pressure centres cause a net accumulation of air, which increases their pressure.
- For a surface low to exist for very long, surface convergence must be maintained by divergence aloft at a rate equal to the inflow below. This process is shown in Fig LT 6-19.

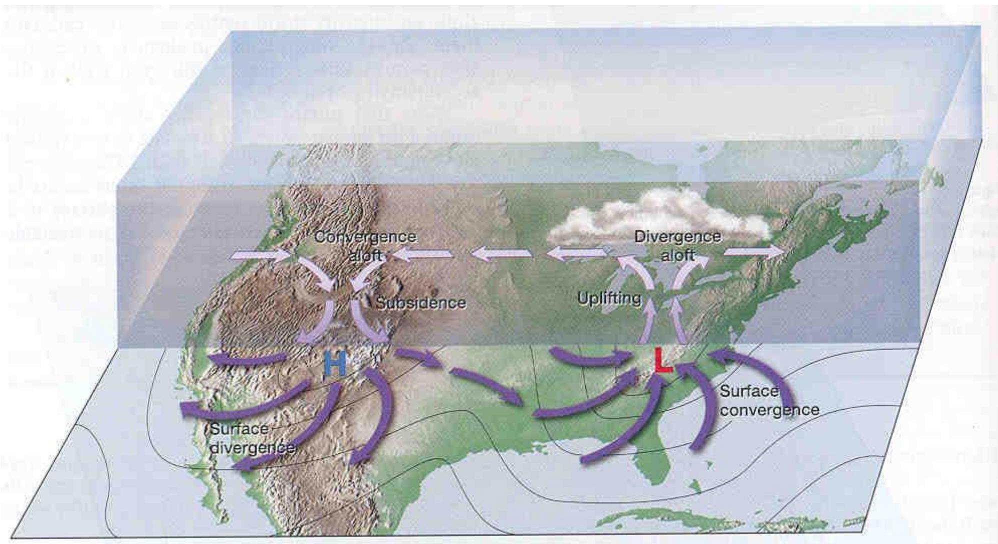
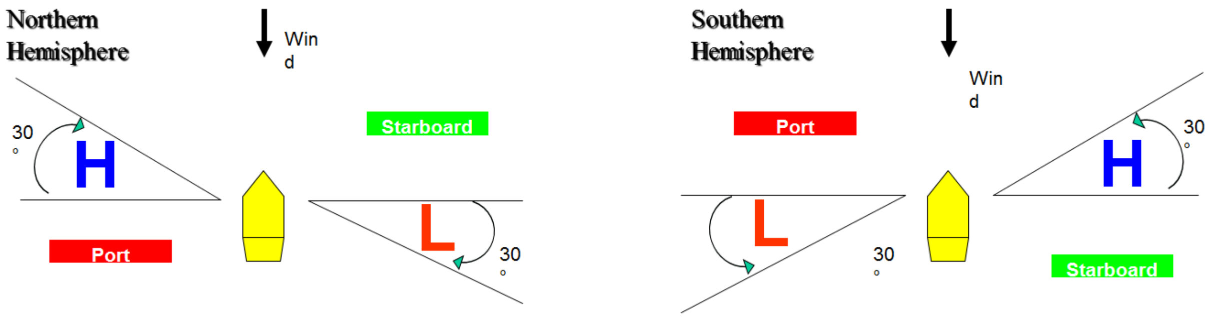
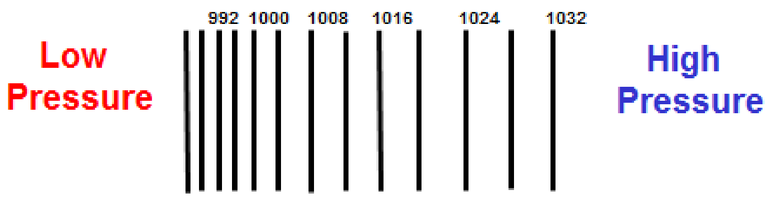


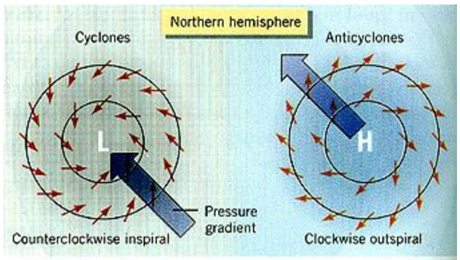
Figure 6–19 Airflow associated with surface cyclones and anticyclones. A low, or cyclone, has converging surface winds and rising air causing cloudy conditions. A high, or anticyclone, has diverging surface winds and descending air, which leads to clear skies and fair weather.

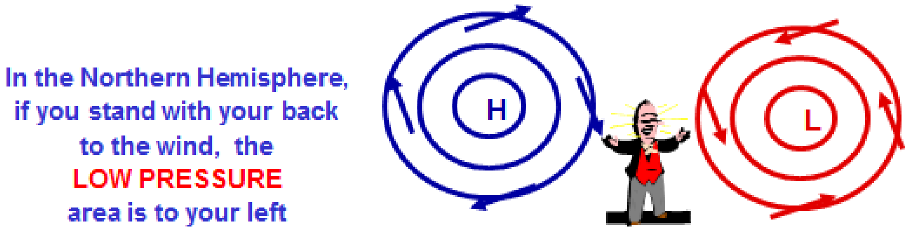
Buys Ballot’s Law

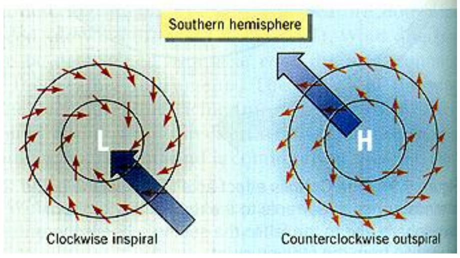
- States that if an observer in the Northern Hemisphere faces the surface wind, the center of the low pressure is toward his right and somewhat behind him (90˚ -120˚)
- And the center of High pressure is on his left and somewhat in front of him(60˚-90˚)
- In the Southern hemisphere its vice versa







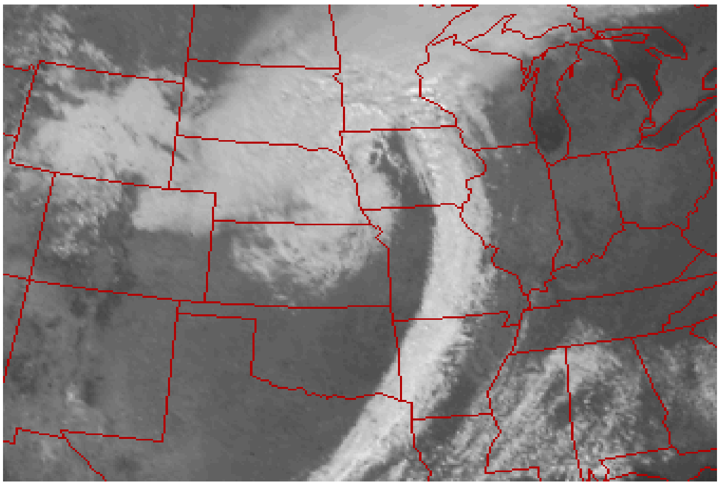


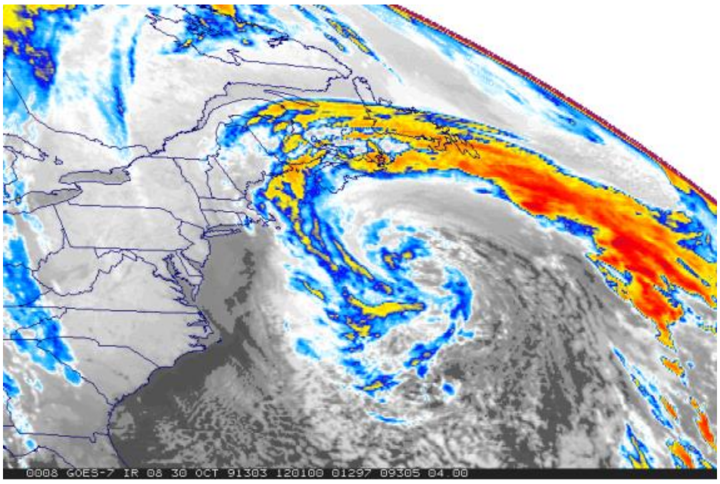


Questions on The winds and the global circulation system

1. What are horizontal pressure gradient, pressure tendency and isobar? How spacing of isobars affect wind speed?
2. Describe with the aid of a sketch the diurnal variation of atmospheric pressure
3. State the effect of friction on geostrophic wind
4. With clear sketches explain how does centrifugal force act around areas of high and low pressures with its effect on gradient wind.
5. Enumerate forces controlling the wind direction, speed and explain each briefly.

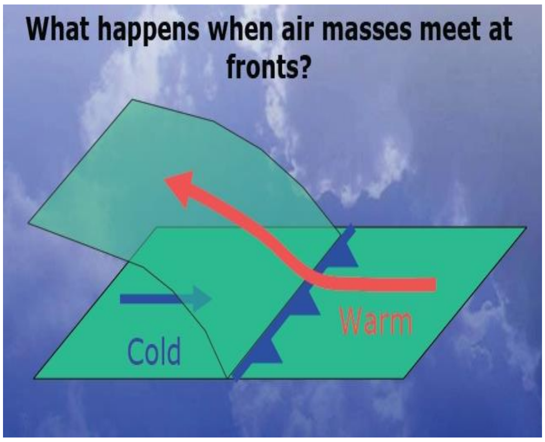
Depressions





Frontal Depressions

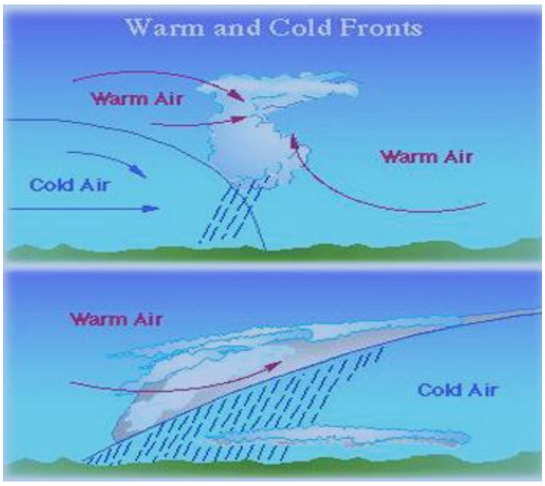
- A frontal depression is a low pressure area formed at the boundary between two different air masses. Frontal depressions occur in middle or high latitudes.
- When a series of them follow one after another, they are referred to as a family of frontal depressions.



Front: A line at the earth surface dividing two air masses.
Frontal Surface (Zone): The surface separating two air masses.

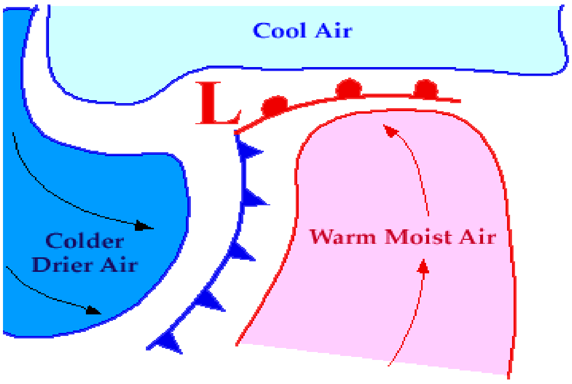
Warm and Cold Fronts

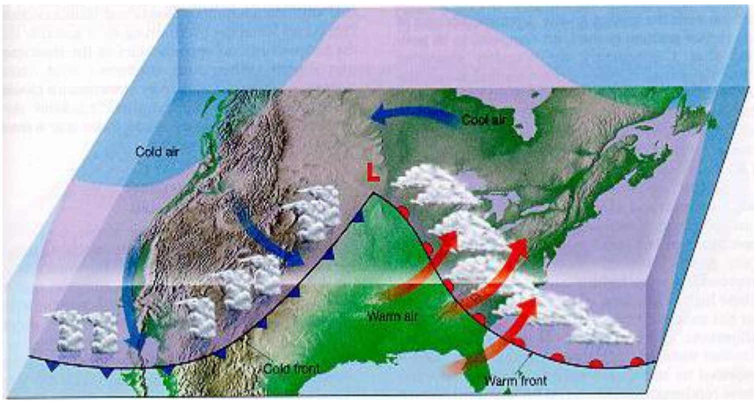
- The effects of a cold front passing over any area or weather station are marked by strong storms followed by clearing and dissipation of their trademark conditions in a few days, with warming being the normal result unless another cold front behind the first moves in before the moderation.
- Warm fronts, on the other hand, develop when low pressure, warmer, moist air overtakes a Cold Front. Again, the warm air glides up and over the cold air mass. Precipitation is over a much broader area and thick nimbostratus and other stratified cloud types are characteristic.



The Principal Frontal Zones in NH

1-The arctic front: In the Atlantic separating arctic air from maritime polar air of the NA
2-The polar front: In the Atlantic which either separates CP air of the N America from MT air of the N A or MP air of the NA from MT air of the NA.
3-Similar to (1&2) arctic and polar fronts in the pacific
4-The Mediterranean front: Separating the cold air over Europe in winter from the warm air over the N Africa
5-The ITCZ (Doldrum): Separating Equatorial air from air of higher latitude.



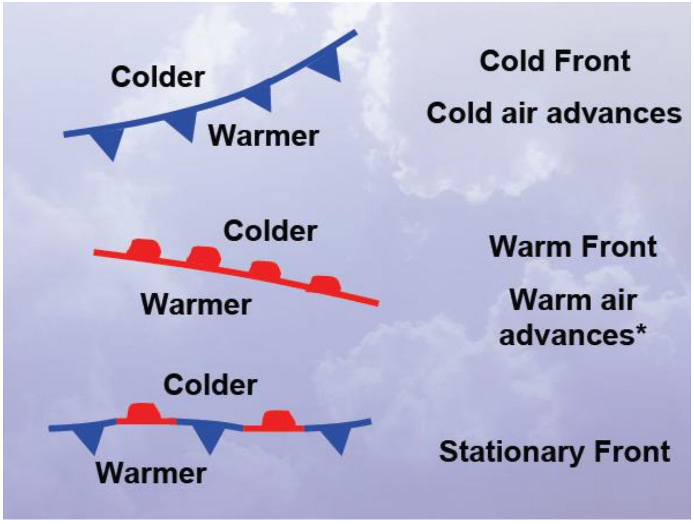


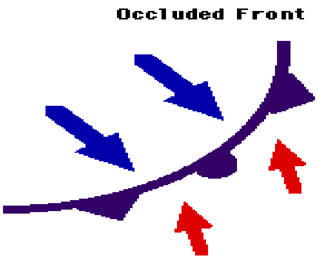
Warm and Cold Fronts

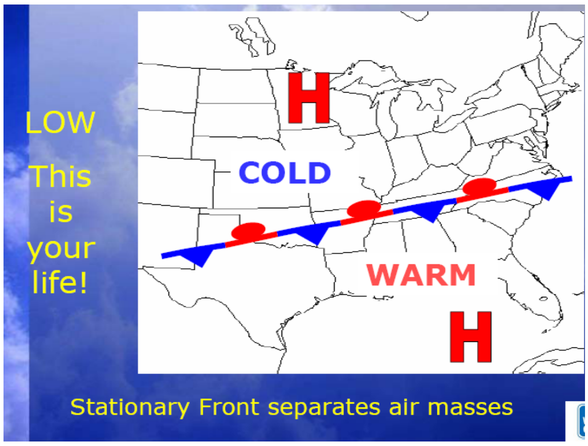
Frontogenesis

Is the formation of frontal depression or the deepening of one already existent.

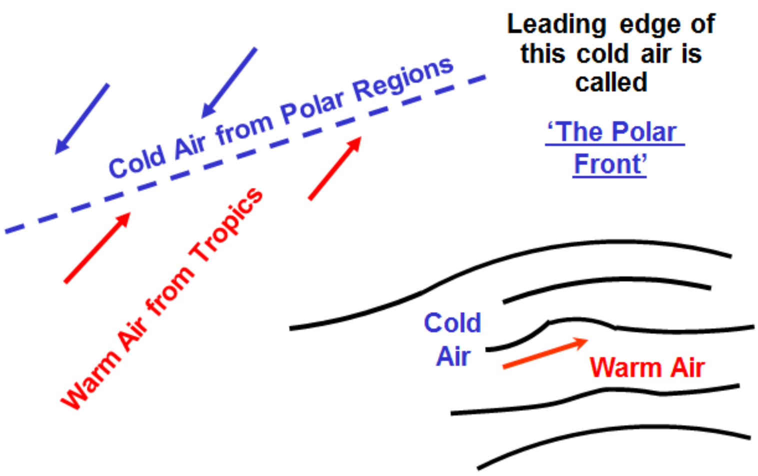
The warm air should be travelling faster than the cold air or they should be travelling in opposite direction





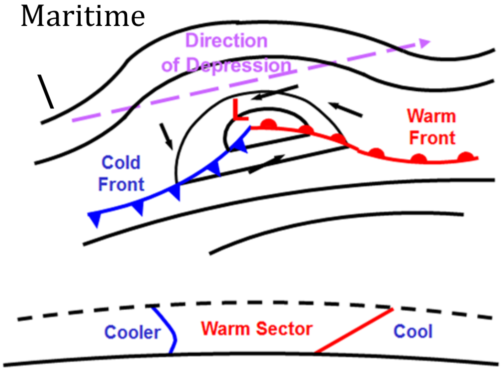


Depression - Birth Stage

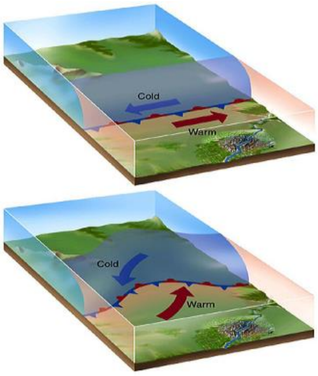


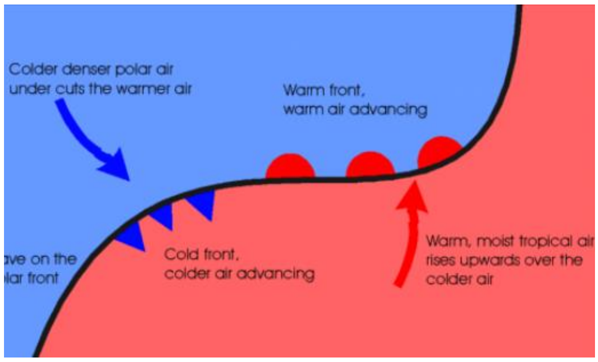
Depression Stage 1

Depressions form where a warm air mass e.g. Tropical Maritime meets a cold air mass e.g. Polar Maritime



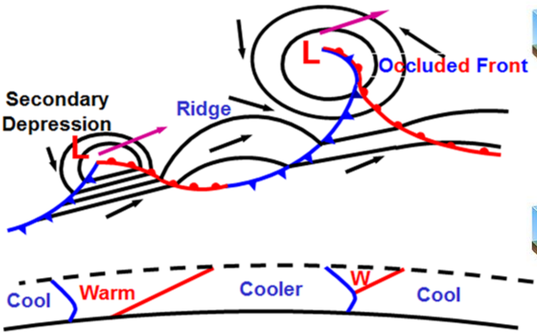
Depression – Classic Stage



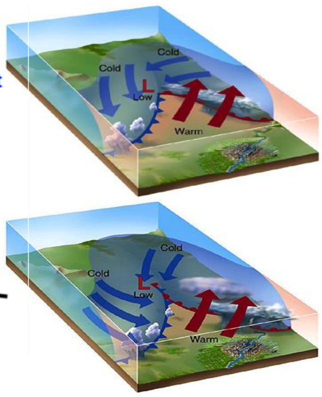


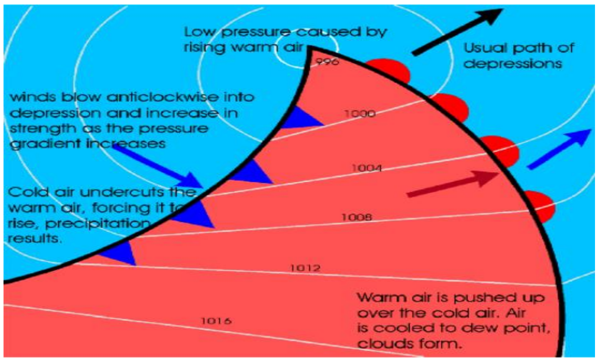
Depression Stage 2 (Maturity)

Rain often occurs along the warm and cold fronts where air rises, expands, cools and condenses



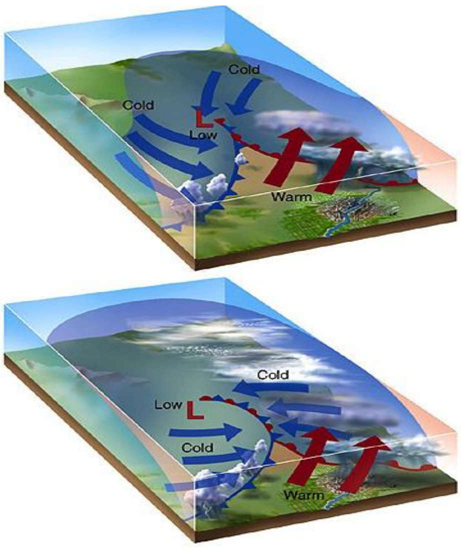
Depression – Mature Stage

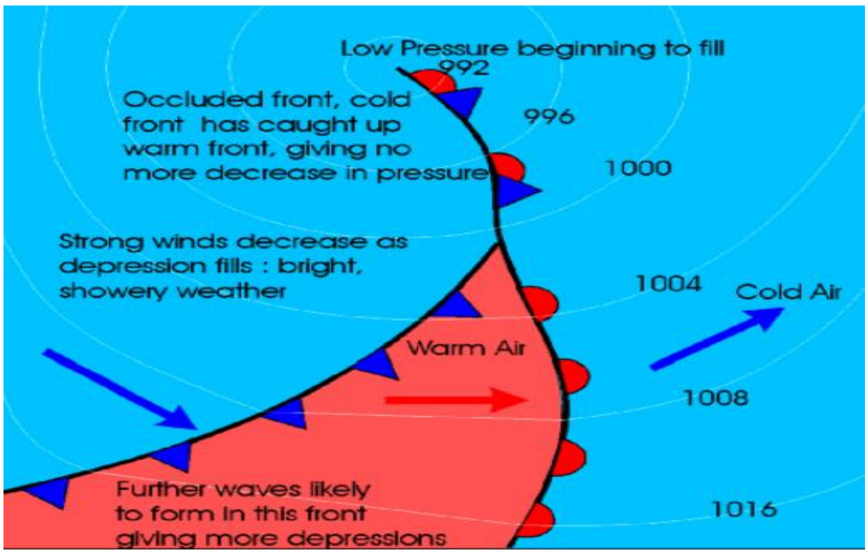




Depression Stage 3 (Occlusion)

The cold front eventually catches up the slower moving warm front to form an occluded front.

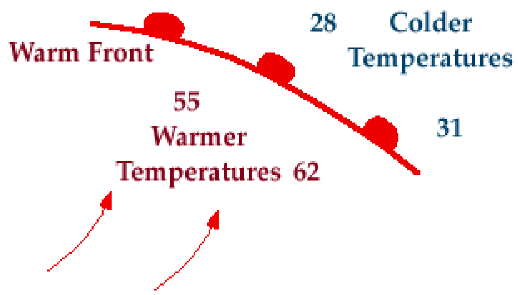




Fronts

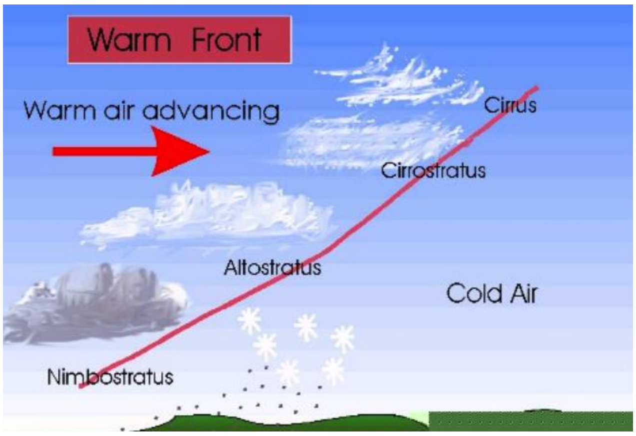
1. **Warm Fronts**
2. **Cold Fronts**
3. **Stationary Fronts**
4. **Occluded Fronts**

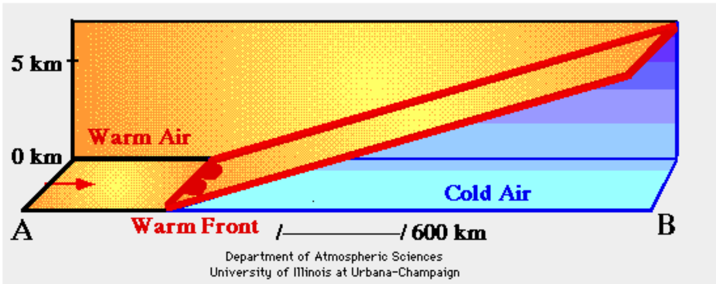
- ## Warm Fronts



A warm front is defined as the transition zone where a warm air mass is replacing a cold air mass. Warm fronts generally move from southwest to northeast and the air behind a warm front is warmer and moister than the air ahead of it. When a warm front passes through, the air becomes noticeably warmer and more humid than it was before.

Precipitation along a Warm Front

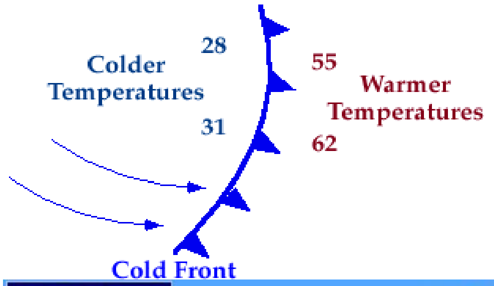


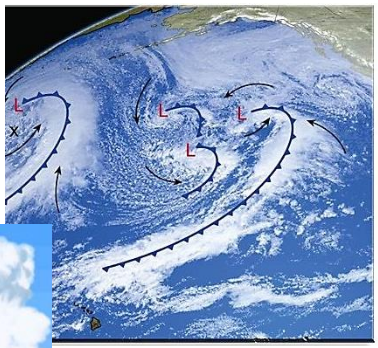


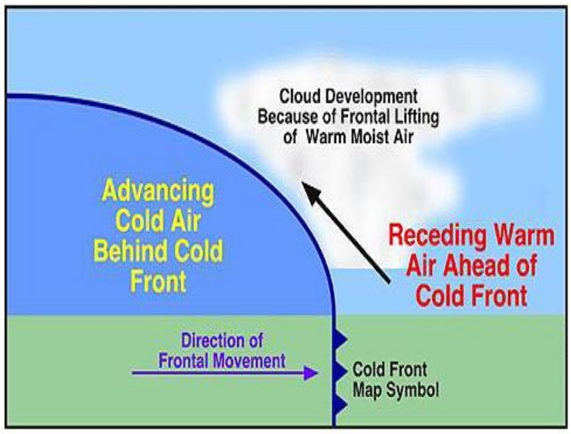
Sequence of Weather at Warm Front			
Element	**In Advance**	**At the Passage**	**In The Rear**
Pressure	Steady Fall	Fall Ceases	Little Change or Slow Fall
Wind (Northern Hemisphere)	Increasing and Sometimes Backing a Little	Veer and Sometimes Decrease	Steady Direction
Temperature	Steady or Slow Rise	Rise, But Not Very Sudden	Little Change
Cloud	Ci, Cs, As, Ns, in Succession; Scud Below As and Ns	Low Ns and Scud	St or Sc
Weather	Continuous Rain or Snow	Precipitation Almost or Completely Stops	Mainly Cloudy, Otherwise Drizzle, or Intermittent Slight Rain
Visibility	Very Good Except in Precipitation	Poor, Often Mist or Fog	Usually Poor; Mist or Fog May Presist

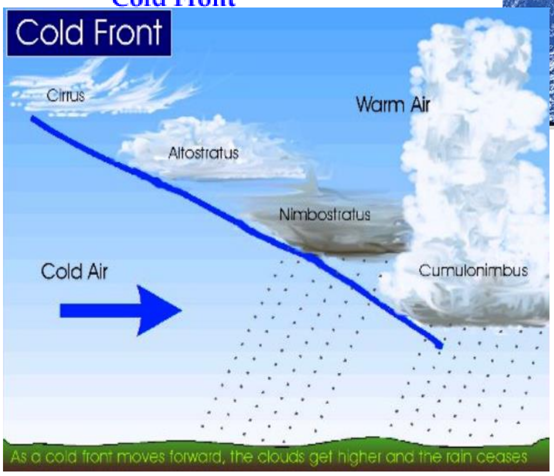
- ## Cold Fronts

A cold front is defined as the transition zone where a cold air mass is replacing a warmer air mass. Cold fronts generally move from northwest to southeast. The air behind a cold front is noticeably colder and drier than the air ahead of it. When a cold front passes through, temperatures can drop more than 15 degrees within the first hour.

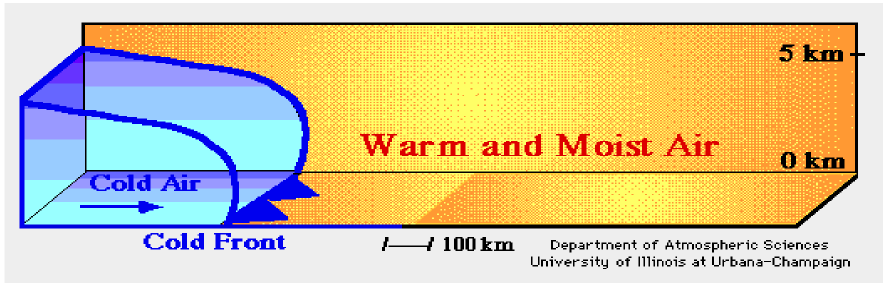






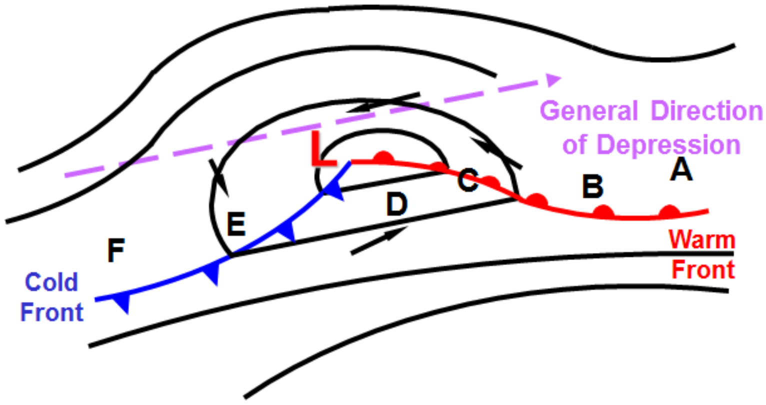


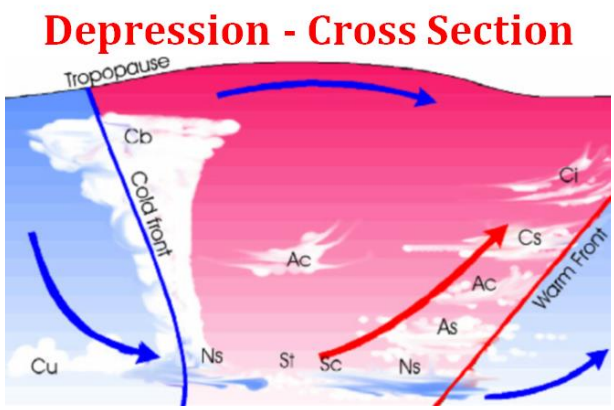
Precipitation along a Cold Front

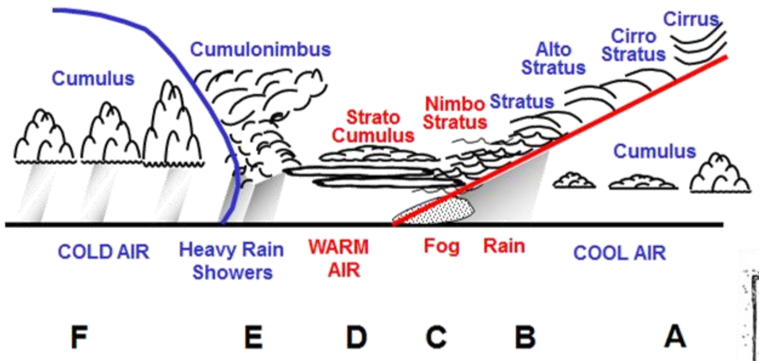


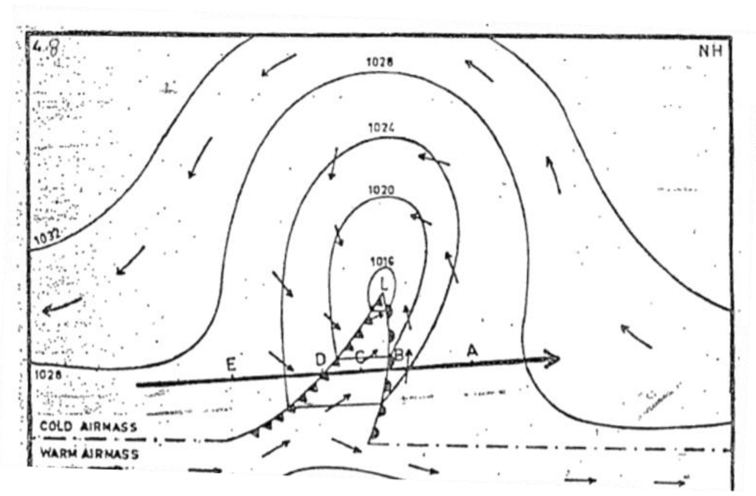
Sequence of Weather at Cold Front			
Element	**In Advance**	**At the Passage**	**In The Rear**
Pressure	Fall	Sudden Rise	Rise Continues More Slowly
Wind (Northern Hemisphere)	Increasing and Backing a Little, Often Becoming Squally	Sudden Veer and Sometimes Heavy Squall	Backing a Little After Squall, Then Often Strengthens and May Steady or Veer Further in a Later Squall
Temperature	Steady, But Fall in Prefrontal Rain	Sudden Fall	Little Change or Perhaps Steady Fall; Variable in Showers
Cloud	Ac or As Then Heavy Cb	Cb with Low Scud	Lifting Rapidly, Followed by As or Ac; Later Further Cu or Cb
Weather	Usually Some Rain; Perhaps Thunder	Rain, Often Heavy, with Perhaps Thunder and Hail	Heavy Rain For Short Period But Sometimes More Persistent, Then Mainly Fair with Occasional Showers
Visibility	Usually Poor	Temporary Deterioration Followed by Rapid Improvement	Usually Very Good Except in Showers

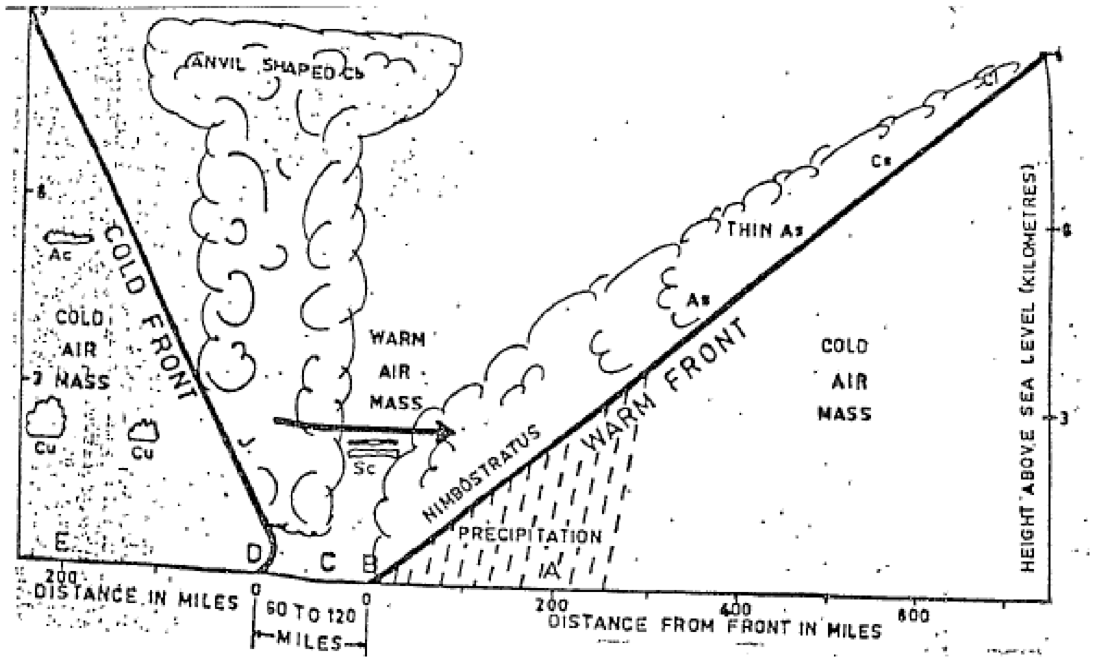
Frontal System







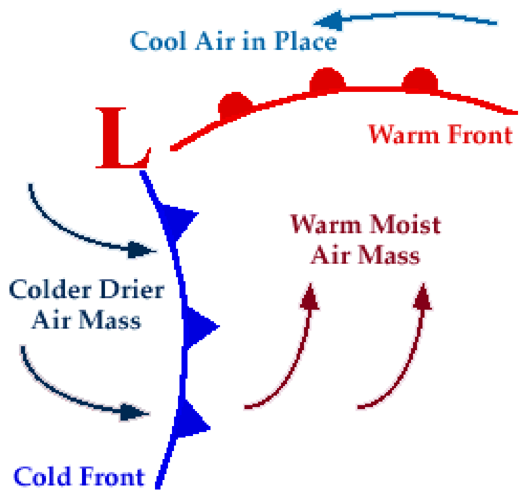


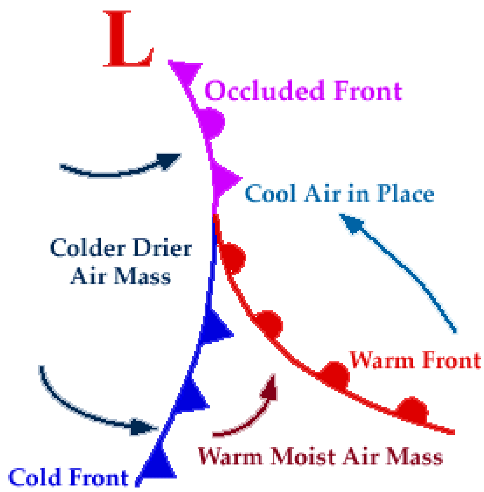


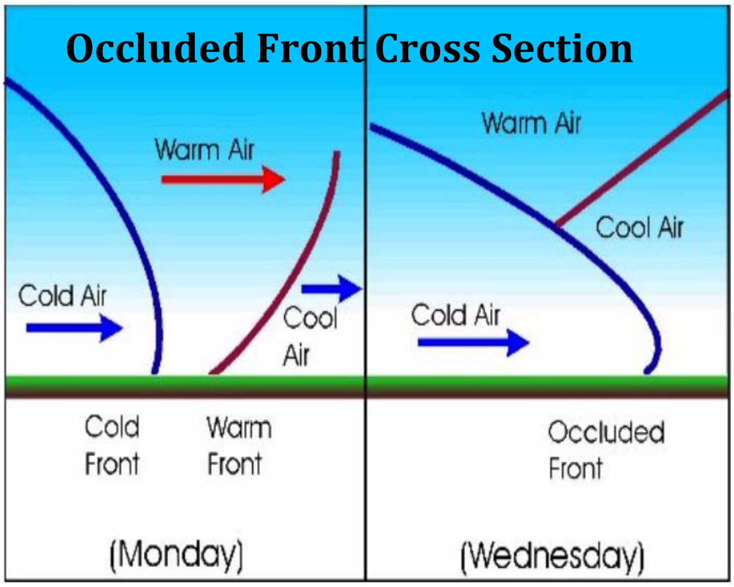
	Warn Front			Cold Front	
Reference Points	In Advance A	At Passage B	Warm Sector C	In Advance D	At Passage E
Pressure	Falls Steadily	Stops Falling and Steading	Constant	Sudden Rise	Rise Slowly
Wind Direction (NH)	Steady	Suddenly Veers by About 90°	Steady	Suddenly Veers by About 90°	Steadies
Wind Force	Increasing	Steady	Steady	Squalls	Gradually Decreases
Temperature	Slow Rise	Quick rise	Steady	Sudden Fall	Steadies
Clouds	Ci, Cs, As	Low Ns	Si or Sc	Cb of very High Vertical Extent	Ac & Cu
Weather	Continuous Heavy Rain or Snow	Precipitation Stops	Cloudy With Occasional Drizzle	Heavy Rain, Thunder, Lightening	Heavy Rain Gives Way to Occasional Showers
Visibility	Very Good Except in Showers	Poor Due to Mist or Fog	Poor Due to Mist or Fog	Poor Due to Rain Squalls	Very Good Except in Showers

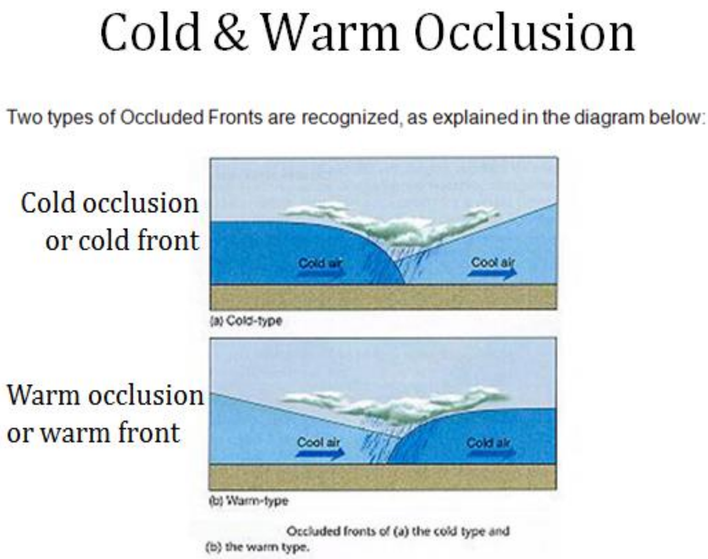
- ## Occluded Fronts

A developing cyclone typically has a preceding warm front (the leading edge of a warm moist air mass) and a faster moving cold front (the leading edge of a colder drier air mass wrapping around the storm). North of the warm front is a mass of cooler air that was in place before the storm even entered the region.

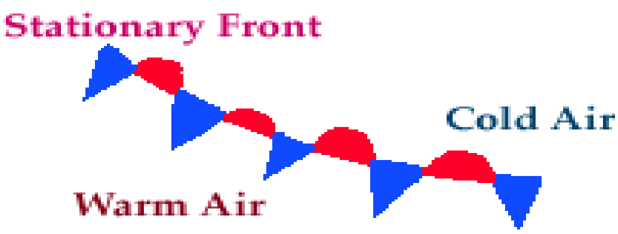








- **Stationary Fronts**



When a warm or cold front stops moving, it becomes a stationary front. Once this boundary resumes its forward motion, it once again becomes a warm front or cold front. A stationary front is represented by alternating blue and red lines with blue triangles pointing towards the warmer air and red semicircles pointing towards the colder air.

- **Frontolysis:**

  Is the weakening or destruction or decay of a frontal depression.

- **Line squall:**

  A cold front is often referred to as line squall because, just before it passes, the long line of low based Cb clouds may be seen which is accompanied by heavy rain or hail and thunder with lightning. Sudden fall of temperature and rise of pressure, veering of wind about 90˚. A line squall may last from 15-30 minutes.

- **Occlusions:**

  When the cold air in front of and behind the warm sector of a frontal depression, under cuts the warm air and lift it completely above sea level.

Cyclones

cyclone is an area of low pressure around which the winds flow counterclockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere. A developing cyclone is typically accompanied by a warm front pushing northward and a cold front pulling southward, marking the leading edges of air masses being wrapped around a center of low pressure, or the center of the cyclone.

The counterclockwise winds associated with northern hemisphere mid-latitude cyclones play a significant role in the movement of air masses, transporting warm moist air northward ahead of a low while dragging colder, drier air southward behind it. Rising air in the vicinity of a low pressure center favors the development of clouds and precipitation, which is why cloudy weather (and likely precipitation) are commonly associated with an area of low pressure.

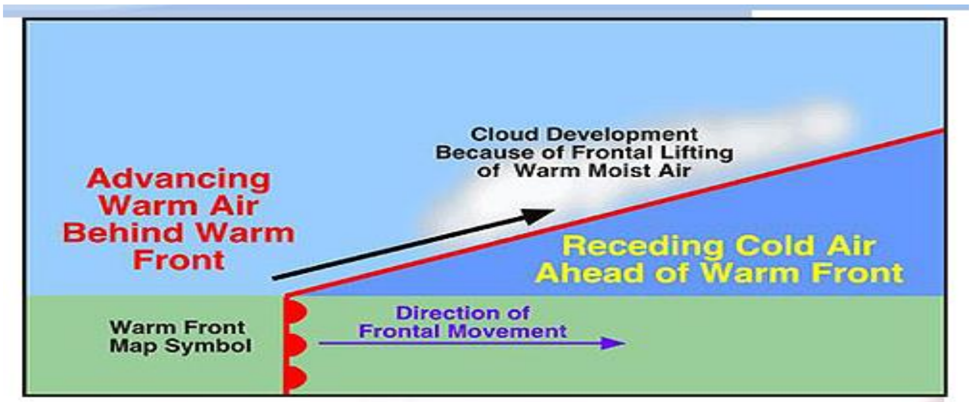
The term usually refers only to tropical cyclones which are limited to defined regions in many of which they are given local names. Cyclone of temperate latitudes are called depressions

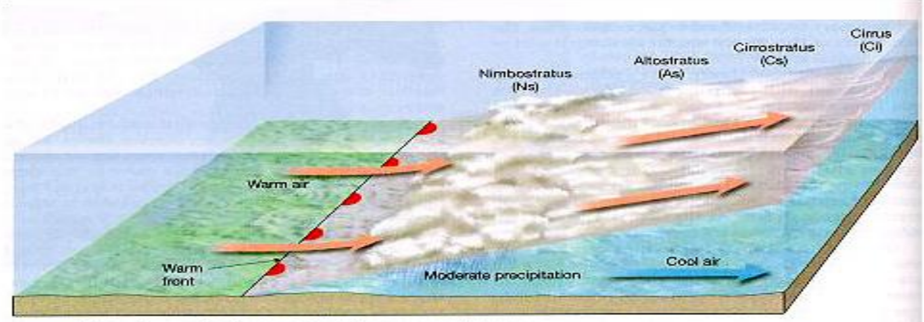
Cyclonic Development Stage 1

The beginning of a large-scale cyclonic development occurs as a northern cold air mass moves south (and often with an eastern component) against an air mass that is cooler, or even describable as warm; each air mass is moving. At this first stage, the boundary between air masses becomes stationary and air above it is in a pressure trough as air diverges horizontally. Air from the surface replaces the upper air and this leads to a pressure drop or a low along the front. At the surface, winds move towards to lower pressure centers and begin to circulate as a counterclockwise inspiral. The process is aided by imbalances in the jet stream where air is forced into uplift. The two fronts - cold and warm - are connected by an extra-tropical cyclone. This strengthens aloft and the process of cyclogenesis begins to produce stormy conditions.

Cyclonic Development Stage 2

With continued pressure drop, the cold front advances into the warm sector and the angle between air masses lessens. During this mature stage, prominent wave shapes are developed in each front (wave cyclones). If the storm tracks to the north of an observation point, that area will receive much rain if temperatures are warm or snow if the near surface conditions are cold. The faster moving cold front eventually overtakes the warm front, developing an occluded state, driving the warm air overhead. In time, the cyclone weakens as the storm moves more to the east. The horizontal pressure gradient diminishes, dissipating the front (frontolysis) and the dissolving stage is reached. After the passage of a mid-latitude low, a high usually follows: If the pressure gradient between air masses is high (steep) a period of strong winds usually results.





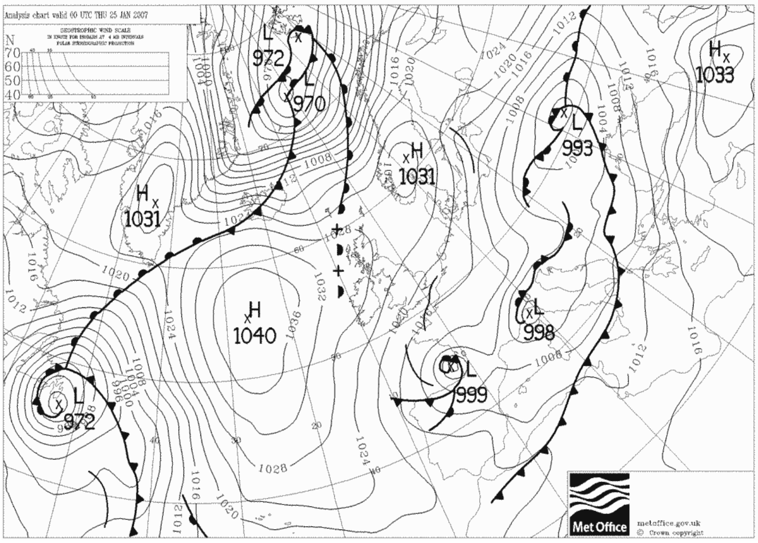
Warm front produced as warm air glides up over a cold air mass.

Noreaster

- For the North American continent, the steering of this cold frontal system is controlled by the Westerlies (winds from the West) and storms in its path come usually from the Canadian West. Maritime polar air masses in the northwest Atlantic can produce east and northeast winds (along the northwest sector of a Low) causing severe storm conditions known as a "**Noreaster**"

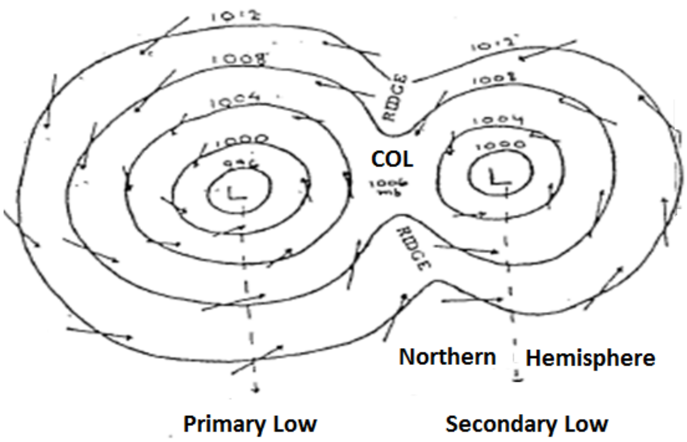
Families of Depression

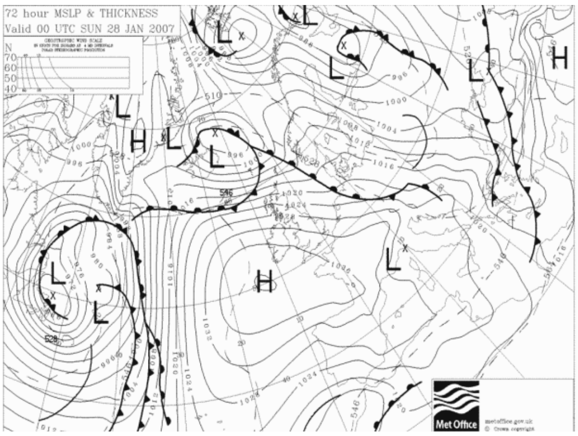
A depression originates as a disturbance on the polar front and dies after its warm sector has been occluded and the center has become remote from the main polar front.The conditions which favored the development of the original depression tend to be reproduced on the relatively slow moving part of the cold front which lies well to the south and west of the position reached by parent depression. This process may be repeated several times and producing families of depression

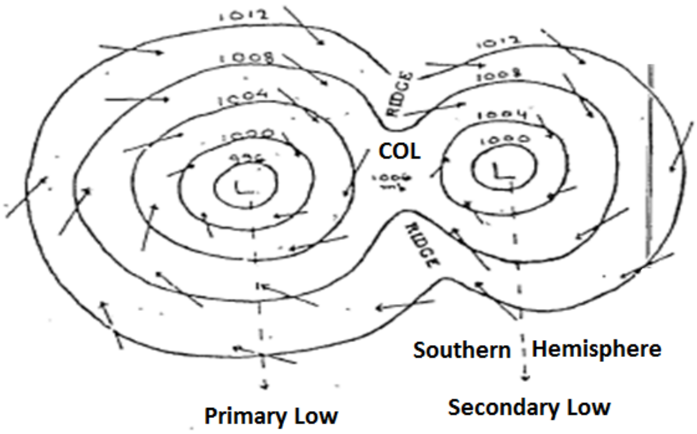


Secondary Depression

A depression embedded in the circulation of a larger or more vigorous depression, known as the primary. In general the secondary moves around the primary in a cyclonic direction. When the primary is weak and secondary strong, it may be absorbed in the circulation of the secondary or the two depressions may rotate around each other.







Non-Frontal Depressions:

These depressions are not connected with frontal zones and include:

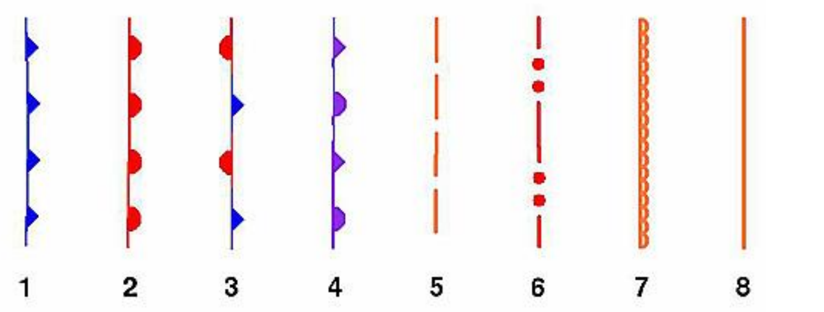
1. **Thermal depressions:**
   Is due to unequal heating of adjacent surface areas, and sea and land distribution plays a big part in determining their location. (e.g. Arabian sea monsoon)

2. **Depression due to vertical instability:**
   Thermal instability in the vertical column of air, especially if the air become saturated. (e.g. formation of TRS)

3. **Depression due to topography(lee depression)**
   If the wind blows across a mountain range which is sufficiently high and continuous to act as a barrier, the resulting distortion of the wind flow leads to the formation of a depression in the lee of the mountain range.

Symbols Used in Making Weather Maps

Some of the symbols used in making weather maps have been introduced in these illustrations. These are the main symbols for Surface Fronts and related features: These symbols are identified as follows: 1) Cold Front; 2) Warm Front; 3) Stationary Front; 4) Occluded Front; 5) Trough; 6) Squall Line; 7) Dry Line; 8) Tropical Wave



Anticyclone or High

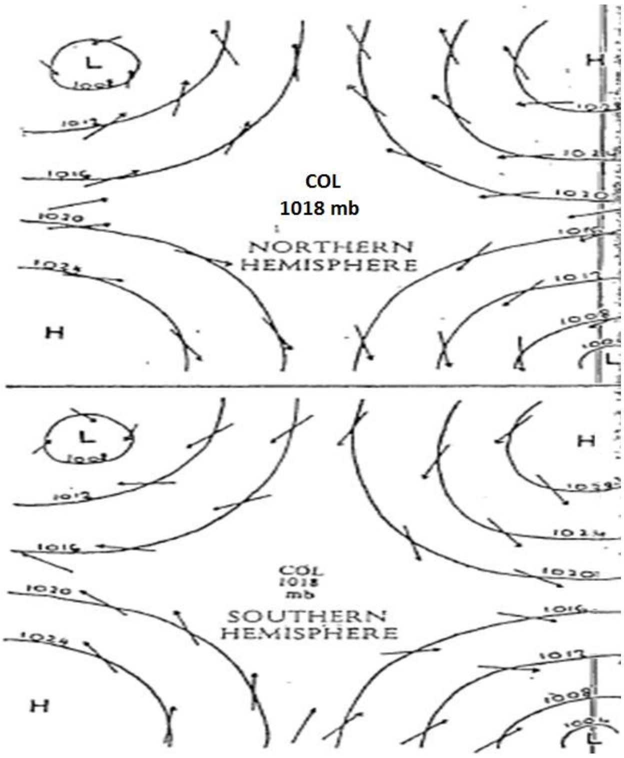
Is an area of high pressure surrounded by areas of low pressure. The isobars form closed shapes. The winds blow spirally outwards, clockwise in NH

Warm and Cold Anticyclone

- If the descending air originally came from a very cold source, it would be colder than the surrounding air at all equal level and called cold anticyclone.
- If the descending air originally came from a warm source, it would be warmer than surrounding air at all equal level and called warm anticyclone.

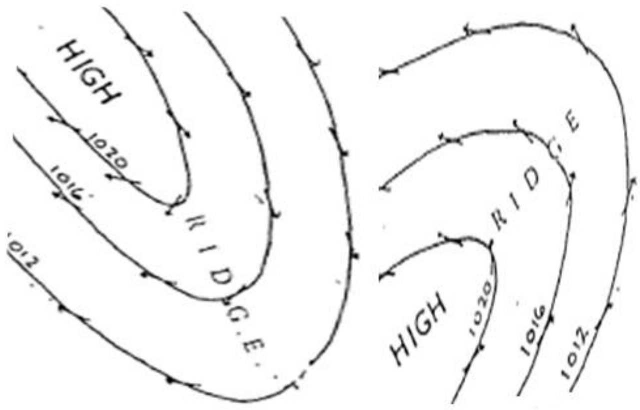
COL

Is an area between two lows and two highs situated alternately. Light variable winds are experienced for short period. R.H is fairly high and lightning may be seen. A COL may be situated between a primary and secondary lows or between the boundary of two different air masses. No definite pattern of weather is associated with a COL.



Ridge of High Pressure

An elongated area of relatively high atmospheric pressure almost always associated with and most clearly identified as an area of maximum anticyclonic curvature of wind flow.



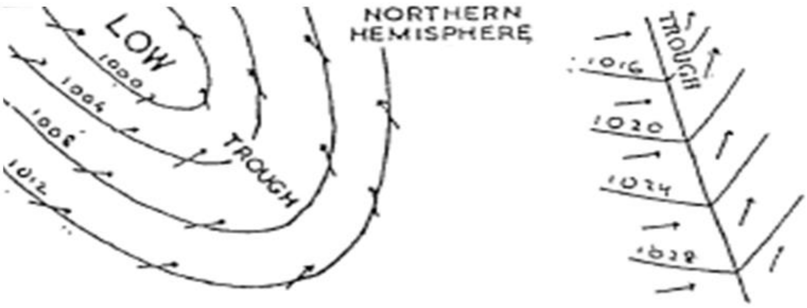
Northern Hemisphere Southern Hemisphere

Trough

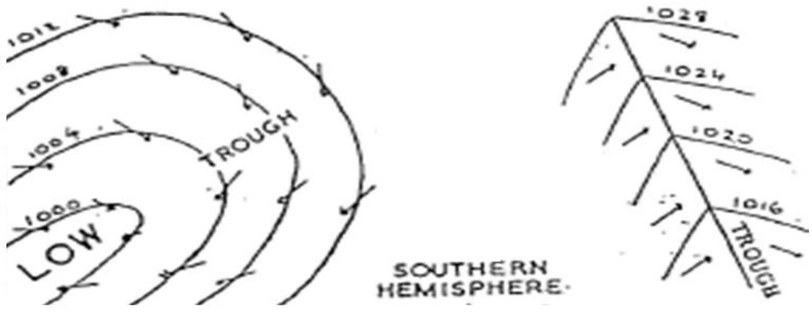
Is an area of low pressure jutting in to areas of high pressure. The isobars are curved with low pressure inside but they do not form necessarily closed shape. The pressure gradient is fairly high resulting in strong winds. Bad weather is associated with trough.

- There are two forms of trough

1) **Non Frontal Trough:** The isobars curve gently.
   When it passes over an observer the wind veers gradually in the N.H and backs in S.H. The U of the non-frontal trough always points towards the equator.
2) **Frontal Trough:** It exists at the boundary between two different air masses. On crossing it, the isobars change direction suddenly (~90˚).
   The V formed the isobars always point towards the equator. When it passes over an observer the wind veers(back in S.H) by about 90˚ . Squalls may be experienced with lightning and heavy shower. Since one air mass is replaced by another, a sudden change of T experienced on its passage



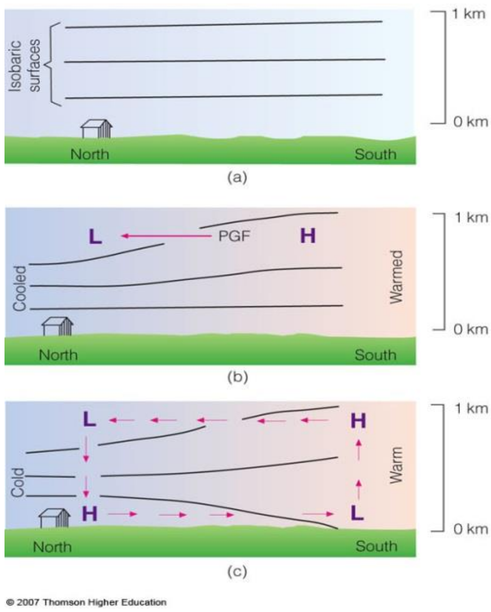
Non Frontal Frontal



Local Winds

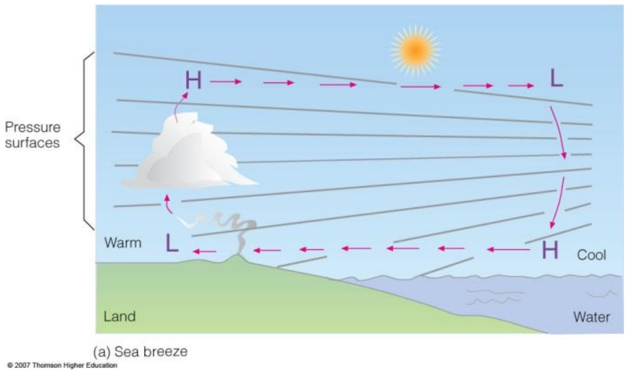
Local Wind Systems (Thermal Circulations)

- Initially, there is no variation in pressure or temp – therefore no wind.
- When the north is cooled and the south is warmed a pressure gradient (more dense & less dense air) is created.
- At the surface, the air pressure changes as the air aloft begin to move. As the air aloft moves from south to north, air leaves the southern area and piles up above the northern area.
- Shallow (1 km) circulation brought on by temp changes is known as a thermal circulation.



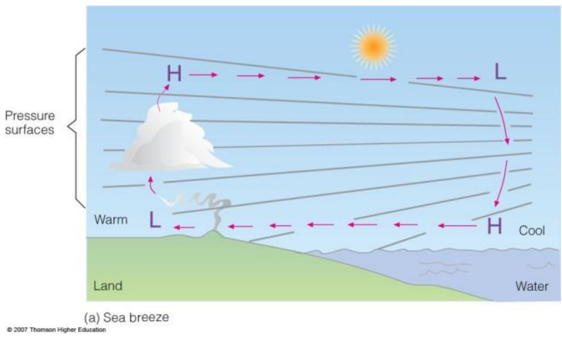
Local Wind Systems (Sea Breeze)

- Type of thermal circulation caused by uneven heating rates of land and water.
- Land heats more quickly during day than the adjacent water.
- The intensive heating of the air above produces a shallow thermal low.
- The air over the water remains relatively cooler than the land, and a shallow thermal high develops above the water.
- Overall effect of this pressure distribution is a sea breeze that blows from the sea toward the land.



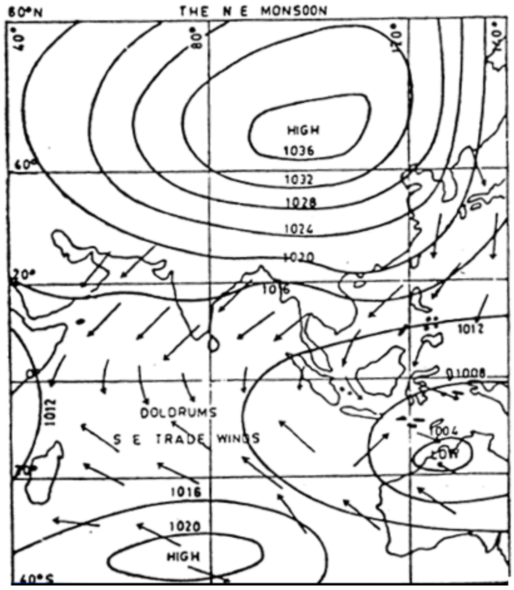
Local Wind Systems (Land Breeze)

- At night, the land cools more quickly than the water.
- With higher surface pressures now over land, the wind reverses itself and becomes a land breeze.
- Land breezes are typically weaker than sea breezes due to a weaker temp contrast.



Local Wind Systems (Monsoon)

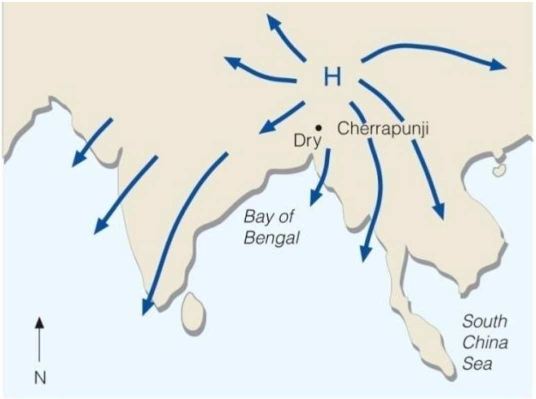
- The word monsoon comes from the Arabic mausim, which means seasons. A monsoon wind system is one that changes direction seasonally.
- One direction in summer, another in winter.
- This seasonal reversal of winds is well developed in Eastern and Southern Asia.
- Similar to a large scale sea breeze.



NE Monsoon

- ✓ In northern winter, the continental air becomes colder than the ocean air.
- ✓ Large High pressure develops over the cold land. (Centered over Siberia with a pressure about 1036mb).
- ✓ The equatorial low of 1012mb, being oceanic and remains practically unaffected by the change of season.
- ✓ Sinking air diverges from the High which is responsible for the fair weather.
- ✓ NE monsoon force is about 3-4 with heavy rain fall over east coast of India.
- ✓ In China Sea PG is larger.
- ✓ Wind force 5-7

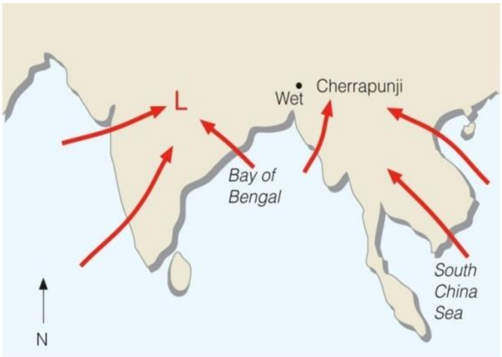
Dry season is between December and February.



(a) Winter Monsoon

SW Monsoon

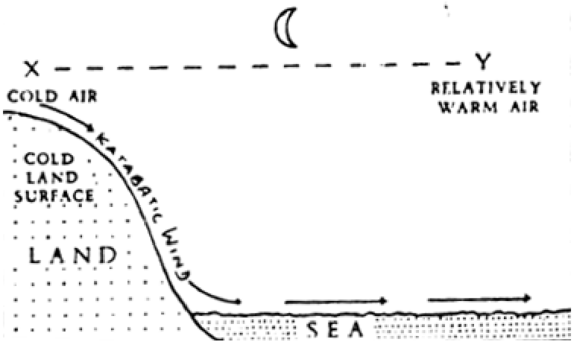
- ✓ In northern summer, air over the continents becomes much warmer than the air over water
- ✓ A shallow thermal low develops over the continent. . (centered over NW India with a pressure of about 994mb which is considerably lower than the equatorial low of 1012mb)
- ✓ A PG develops from the equator towards the NW India
- ✓ Air rises at the center of the low, initiates convergence.
- ✓ The SE trade winds blowing from oceanic high at 30˚ S towards the equatorial low crosses over the equator and blow as strong SW wind(force 7-8) towards the low over NW India.
- ✓ This causes moist winds from the ocean to blow inland.
- ✓ Hills and mountains provide additional lift.
- ✓ Rainy season is from June to September.



(b) Summer Monsoon

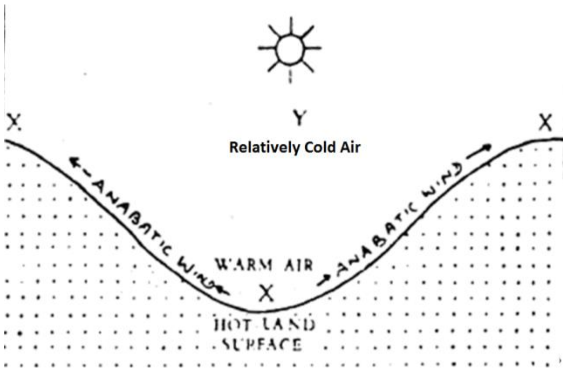
Katabatic Wind

When the earth's surface cools by night, the air next to the surface is also cooled and its density is increased. If this cold air is on high ground, there is a tendency for it to sink down to lower ground. If the high ground is on sea side, the down flowing cold air will move horizontally when it reaches sea level, which may reach force 6-7.
(e.g. Coast of green land and Adriatic regions)



Anabatic Wind

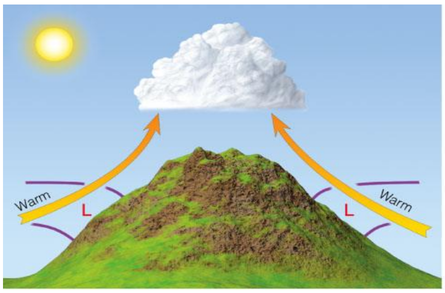
This wind is less noticeable as it blows up the sides of valleys with considerably less force than the katabatic wind. The air at the bottom of the valley is warmed by conduction from the heated land during the day and this air being less dense than the air above it, flows to the top of the valley by following the warm sides



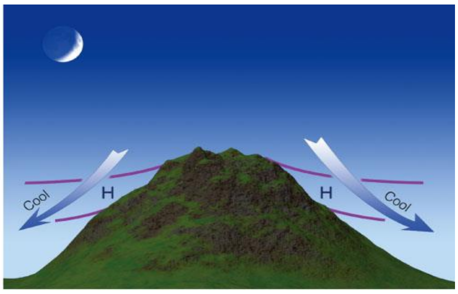
Mountain and Valley Breezes

Similar to sea and land breezes

During the day, sunlight warms valley walls, which warm the air in contact with them. The heated air rises and forms the valley breeze.



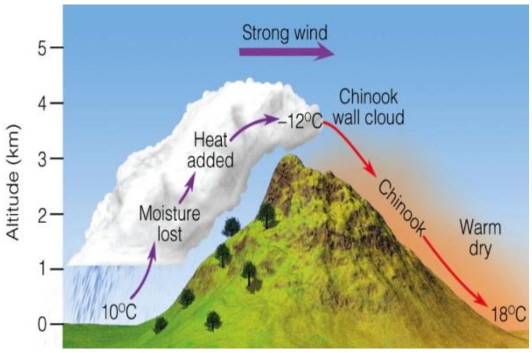
Valley breeze



Mountain breeze

During the night, the slopes cool quickly, chilling the air in contact with them. The cool air sinks and forms mountain breeze.

Chinook/Foehn Winds



This is felt on lee side of high ground and results in temperatures on the lee side being higher than those on the weather side if the air passing over the high ground has been cooled to below its dew point. As the air rises on weather side, it cools to its dew point and as precipitation occurs, the absolute humidity decreases. Due to decrease in absolute humidity, the dew point temperature on the lee side will be considerably lower than that on the weather side which means that the condensation level will be higher on the lee side.
Below the condensation level the air will change its temperature at the DALR, whilst above it, it will change its temperature at SALR. As the condensation level on the lee side is higher than on the weather side it follows that the descending air will warm at a greater rate than the ascending air cools, this results in higher temperature on the lee side

Tornado and Waterspout

- A tornado is a violent whirlwind of the cyclonic type. Its axis is nearly vertical, extending from the cloud base downwards and often reaching ground level.
- Condition most favorable for their formation are when MP air from a NWLY direction overruns MT air from the Gulf of Mexico , leading to a steep lapse rate and great instability and formation of Tornado some distance ahead of the surface cold front.
- Its internal pressure may be <20% of external air.
- Its width is 50-500m with wind of often hurricane force.(up to 400KM/Hr)
- Generally travel at speed of 10-30 kts from east to west and may last from a few minutes to a few days, covering a track of a few hundred meters to a few hundred miles.

Cause an intense upward current at the center capable of lifting heavy objects. If develop over desert then it called dust devil.
Tornadoes are associated with isolated Cb clouds.
The formation requires great instability, high humidity, and convergence at low levels (similar conditions for formation of thunder storm)
Areas of occurrence: mostly US continent and west Africa area.
When passes over sea, large quantities of water are carried up by the vertical current of air at the center, forming a water spout which appears as a thin funnel shaped, opaque column, and broad at the top and very thin at the sea level.

BORA

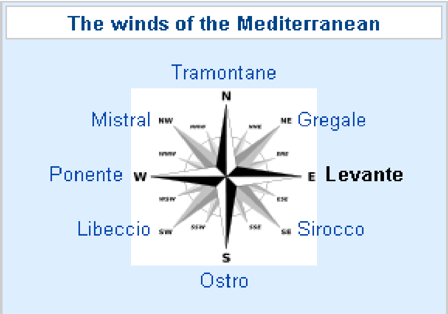
- Is a Katabatic wind that blows over the north and east coast of the Adriatic sea, from a direction between N and E.
- It can attain gale force in a very short time without the usual warning indicated by barometric pressure.
- It can be a danger to ships at anchor.

Gregale

- A strong NE wind found in the central and western Mediterranean sea which is important for ships in port of Malta and east coast of Sicily where the ports are open to NE winds. It occurs mainly in the winter and after passage of a depression.

Levanter

- A light to moderate east wind in the strait of Gibraltar accompanied with excessive moisture, cloud, haze, or fog and sometimes rain.
- When blowing moderately or strongly, the Levant causes heavy swells on the Mediterranean. Usually gentle and damp, the Levant frequently brings clouds and rain.



Khamsin

- A southerly wind which blows in Egypt and in the Red sea ahead of eastward moving depressions. It is liable to be strong and as it blows from African interior, it is hot, dry, and often dusty. It occurs from Feb- June and is most frequent in March and April.\

Shamal

- Is any NW wind in the Persian or Oman Gulfs.
- It is a warm, dusty, dry wind from the desert of Arabia. It may change direction and blow from W or SW.
- No indication is given by barometric P of the approaching of a Shamal, though the wind force at winter can reach force 8-9, sometimes with rain squalls, thunder and lightning.
- It is more continuous in summer than winter and is most frequent in N PG.
- Occurrence of heavy NW swell especially in south of PG

Ship's Weather Reporting

SOLAS Chapter 5 Safety of Navigation

Regulation 1 - Application

Unless expressly provided in regulations 1& 3 otherwise, this chapter shall apply to all ships on all voyages.

Regulation 4 - Navigational Warnings

Each Contracting Government shall take all steps necessary to ensure that, when intelligence of any dangers is received from whatever reliable sources, it shall be promptly brought to the knowledge of those concerned and communicated to other interested governments.

Regulation 5 - Meteorological Services and Warnings

Contracting Governments undertake to encourage the collection of meteorological data by ships at sea and to arrange for their examination, dissemination and exchange in the manner most suitable for the purpose of aiding navigation. Administrations shall encourage the use of meteorological instruments of a high degree of accuracy and shall facilitate the checking of such instruments upon request. Arrangements may be made by appropriate national meteorological services for this checking to be undertaken, free of charge to the ship.

Contracting Governments Responsibility

1- To warn ships of gales, storms and tropical cyclones by the issue of information in text and, as far as practicable, graphic form, using the appropriate shore-based facilities for terrestrial and space radio communications services.

2 -To issue, **at least twice daily**, by terrestrial and space radio communication services, as appropriate, weather information suitable for shipping containing data, analyses, warnings and forecasts of weather, waves and ice. Such information shall be transmitted **in text and, as far as practicable, graphic form**, including meteorological analysis and prognosis charts transmitted by facsimile or in digital form for reconstitution on board the ship's data processing system.

3 -To prepare and issue such publications as may be necessary for the efficient conduct of meteorological work at sea and to arrange, if practicable, for the publication and making available of daily weather charts for the information of departing ships.

4- To arrange for a selection of ships to be equipped with tested marine meteorological instruments (such as a barometer, a barograph, a psychrometer and suitable apparatus for measuring sea temperature) for use in this service, and to take, record and transmit meteorological observations at the main standard times for surface synoptic observations and to encourage other ships to take, record and transmit observations in a modified form, particularly when in areas where shipping is sparse.

5- When in the vicinity of a tropical cyclone, or of a suspected tropical cyclone, ships should be encouraged to take and transmit their observations at more frequent intervals whenever practicable, bearing in mind navigational preoccupations of ships' officers during storm conditions.

6- To encourage masters to inform ships in the vicinity and also shore stations whenever they experience a wind speed of 50 knots or more (force 10 on the Beaufort scale).

Regulation 6 - Ice Patrol Service

The Ice Patrol contributes to safety of life at sea, safety and efficiency of navigation and protection of the marine environment in the North Atlantic. Ships transiting the region of icebergs guarded by the Ice Patrol during the ice season are required to make use of the services provided by the Ice Patrol.

Regulation 31 - Master obligation (Danger messages)

1- The master of every ship which meets with dangerous ice, a dangerous derelict, or any other direct danger to navigation, or a tropical storm, or encounters sub-freezing air temperatures associated with gale force winds causing severe ice accretion on superstructures, or winds of force 10 or above on the Beaufort scale for which no storm warning has been received, is bound to communicate the information by all means at his disposal to ships in the vicinity, and also to the competent authorities. The form in which the information is sent is not obligatory. It may be transmitted either in plain language (preferably English) or by means of the International Code of Signals.

2 -Each Contracting Government will take all steps necessary to ensure that when intelligence of any of the dangers specified in paragraph 1 is received, it will be promptly brought to the knowledge of those concerned and communicated to other interested Governments.

3 -The transmission of messages regarding the dangers specified is free of cost to the ships concerned.

4 -All radio messages issued under paragraph 1 shall be preceded by the safety signal

Regulation 32 - Information Required in Danger Messages

1) Ice, derelicts and other direct dangers to navigation:
- The kind of ice, derelict or danger observed.
- The position of the ice, derelict or danger when last observed.
- The time and date (GMT) when the danger was last observed

2) Tropical cyclones (storms):
- A statement that a tropical cyclone has been encountered
- Time, date (GMT) and position of ship when the observation was taken.
- As much of the following information as is practicable should be included in the message:

— Barometric pressure;
— Barometric tendency (the change in barometric pressure during the past three hours);
— True wind direction;
— Wind force (Beaufort scale);
— State of the sea (smooth, moderate, rough, high);
— swell (slight, moderate, heavy) and the true direction from which it comes. Period or length of swell (short, average, long) would also be of value;
— true course and speed of ship

3-When a master has reported a tropical cyclone or other dangerous storm, it is desirable, but not obligatory, that further observations be made and transmitted hourly, if practicable, but in any case at intervals of not more than 3 hours, so long as the ship remains under the influence of the storm. (Subsequent Observation)

4 -Winds of force 10 or above on the Beaufort scale for which no storm warning has been received. This is intended to deal with storms other than the tropical cyclones referred to in paragraph 2; when such a storm is encountered, the message should contain similar information to that listed under the paragraph but excluding the details concerning sea and swell.

5- Sub-freezing air temperatures associated with gale force winds causing severe ice accretion on superstructures:

- Time and date (GMT)
- Air temperature
- Sea temperature (if practicable)
- Wind force and direction.
- Ship's position

Examples Reporting

Ice

TTT ICE. LARGE BERG SIGHTED IN 4 5 0 6 N, 4 4 1 0 W, AT 0 8 0 0 UTC. MAY 1 5.

Derelicts

TTT DERELICT. OBSERVED DERELICT ALMOST SUBMERGED IN 4 0 0 6 N, 1 2 4 3 W, AT 1 6 3 0 UTC. APRIL 2 1.

Danger to navigation

TTT NAVIGATION . ALPHA LIGHTSHIP NOT ON STATION . 1 8 0 0 UTC . JANUARY 3 .

Tropical cyclone

TTT STORM. 0 0 3 0 UTC. AUGUST 1 8 . 2 0 0 4 N, 1 1 3 5 4 E. BAROMETER CORRECTED 994

MILLIBARS, TENDENCY DOWN 6 MILLIBARS. WIND NW, FORCE 9, HEAVY SQUALLS. HEAVY

EASTERLY SWELL. COURSE 0 6 7 , 5 KNOTS.

Storm

TTT STORM. WIND FORCE 1 1 , NO STORM WARNING RECEIVED. 0 3 0 0 UTC . MAY 4 . 4 8 3 0 N, 30 W. BAROMETER CORRECTED 9 8 3 MILLIBARS , TENDENCY DOWN 4 MILLIBARS . WIND SW, FORCE 11 VEERING. COURSE 2 6 0 , 6 KNOTS .

Icing

TTT EXPERIENCING SEVERE ICING. 1 4 0 0 UTC. MARCH 2. 69 N, 10 W. AIR TEMPERATURE

18 F (- 7 . 8 ° C) . SEA TEMPERATURE 29°F (- 1 . 7'C) . WIND NE , FORCE 8 .

Weather Routeing

- **Objectives**
  - Objectives of Weather Routeing
  - Types of Routeing Services
  - Ship Performance Curves
  - Least Time Track
  - Route Selection Parameters
  - Routeing Services Ashore
  - Ship And Shore Based Routeing

Definition:
Weather Routing is the art of achieving a safe and economic passage across an ocean, taking in to consideration all available meteorological and oceanographical factors.

Purpose of ship's routing:

- Navigate the v/l on the best route that avoids the worst of weather conditions.
- Avoids area of fog or ice
- Take advantages of currents, less fuel consumption
- Reduction of heavy weather damages
- Less passage time

Types of Weather Routing Services:

- Least time tracks (tankers)
- Least time with least damage to hull and cargo (general cargo)
- Least damage (livestock)
- Constant speed (container ship)
- Fuel saving

Factors Influencing Weather Routing

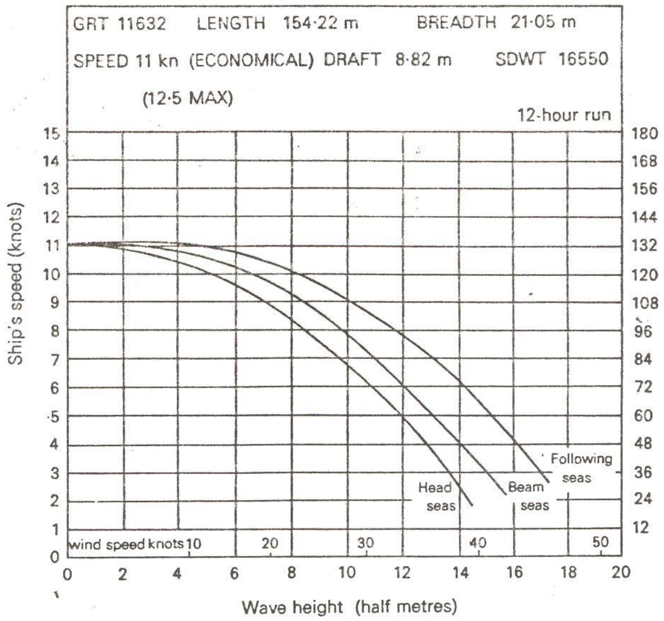
- Distance
- Currents
- Time of year, wind and waves
- Areas of ice, fog, TRS and navigational hazards
- Low temperatures
- Type of vessel and navigational equipment
- State of loading, nature of cargo, load line zone

Climatological Routing
It consists of following generally accepted Transocean routes usually on summer/ winter bases. (N.I. ocean)

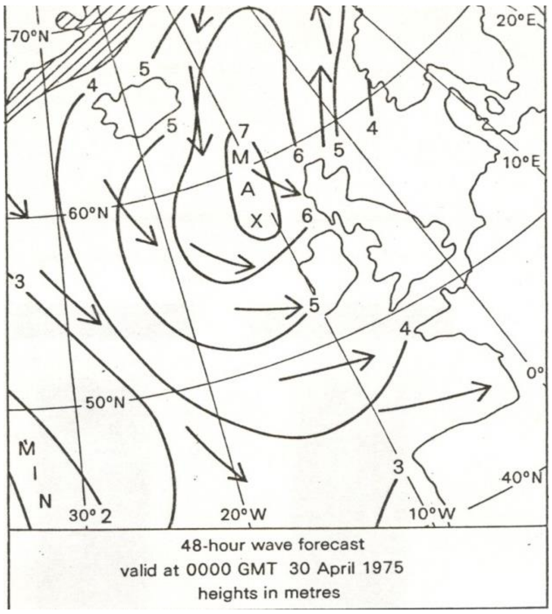
- ✓ Uses pilot books
- ✓ Routeing charts
- ✓ Ocean passages of the world
- ✓ Relies on predicted weather patterns
- ✓ Cannot be used reliably in the North Atlantic and North Pacific because of changing weather

- ✓ In areas that changes of weather is frequent(N.A & N.P oceans)
- ✓ Made possible by International co-operation
- ✓ Weather situations can now be predicted with reasonable accuracy up to 72 hrs
- ✓ Ships performance is affected by waves

Performance curves: the details of how the ship will perform in various sea states



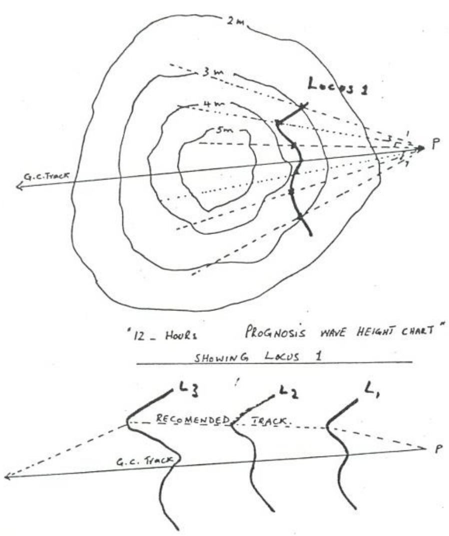
Wave Chart



Weather Routing By Shipmaster (Climatic Routing)

- Draw shortest possible track
- Transfer to transparent plastic sheet
- Placed over a 24 hr prognostic wave chart
- Radial lines 100 apart
- Performance curves consulted
- Likely position on these courses after 24 hrs
- Joined, to form a time front(locus)
- Project several of these fronts for projected later forecasts (48 hrs, 72 hrs etc.)
- Determine least time track
- Amend as required

Lease Time Track



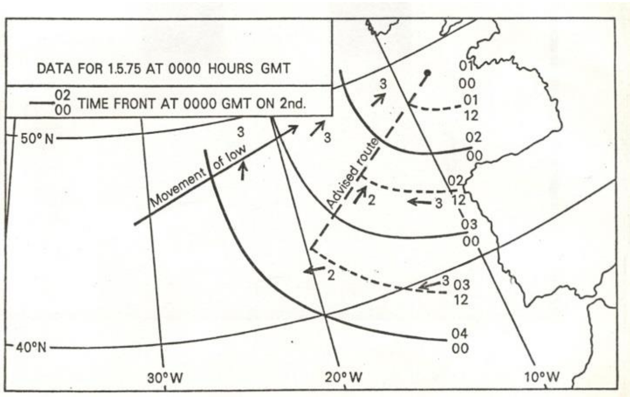
Information requires by shore ORG

- Ship's particulars
- Port of departure and arrival
- Date and time of departure
- Ship's speed, draft, free board and trim
- Details of cargo
- Any particular preference of master
- Any special requirement

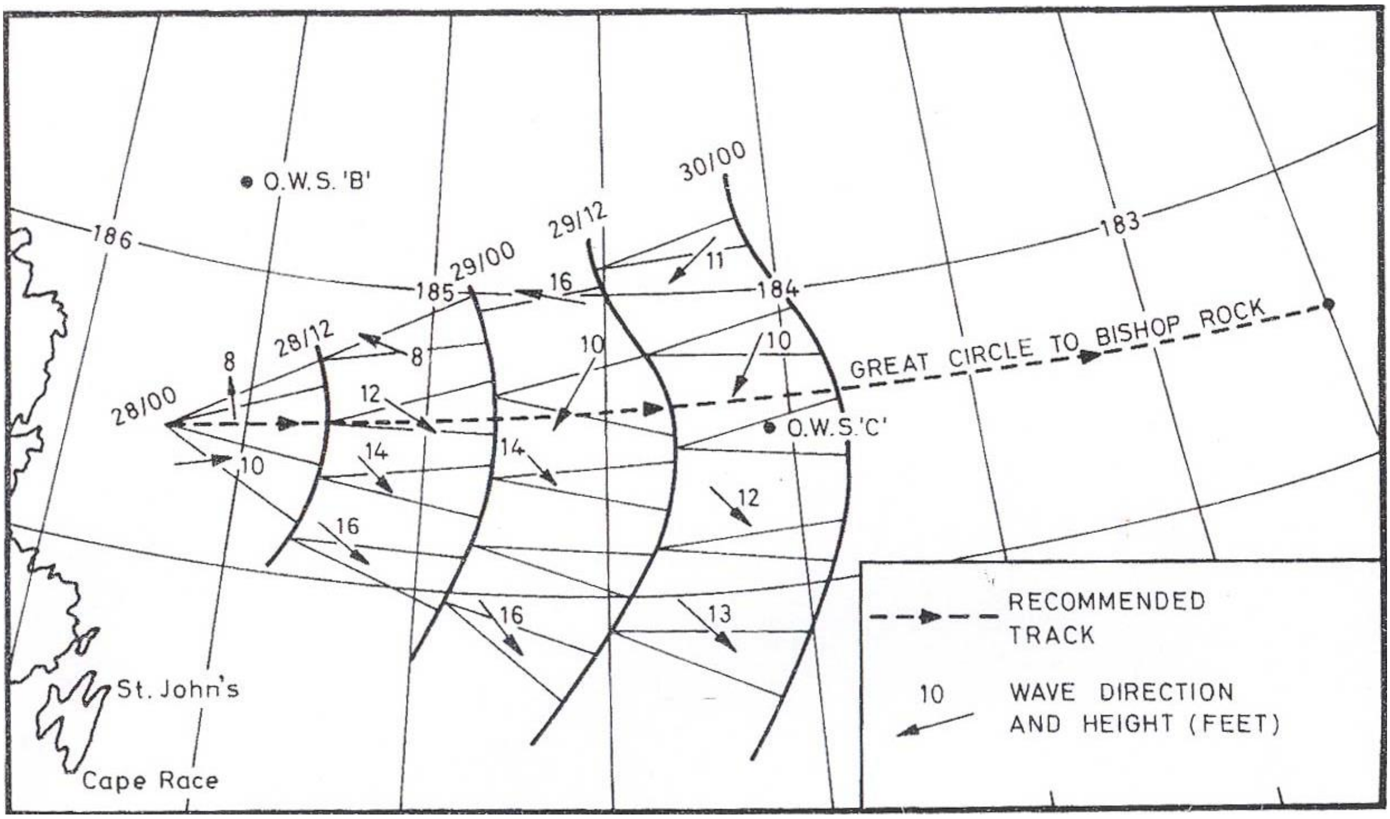
Ship Routing Ashore

- ✓ Forecast wind, wave fields by computer
- ✓ Apply forecast to performance curves
- ✓ 12 hour distance on various courses
- ✓ Join travel points to form time front
- ✓ Project several 12 hourly time fronts
- ✓ Determine least time track
- ✓ Consider – navigation safety, load line zones, ocean currents, fog, ice etc
- ✓ Advise route and expected weather
- ✓ Monitor progress, using ships weather reports(every 24 hrs)
- ✓ Repeat daily and modify as required
- ✓ Advisory or diversion message

Time Fronts



Lease Time Track



Limitations

Performance curve limitations

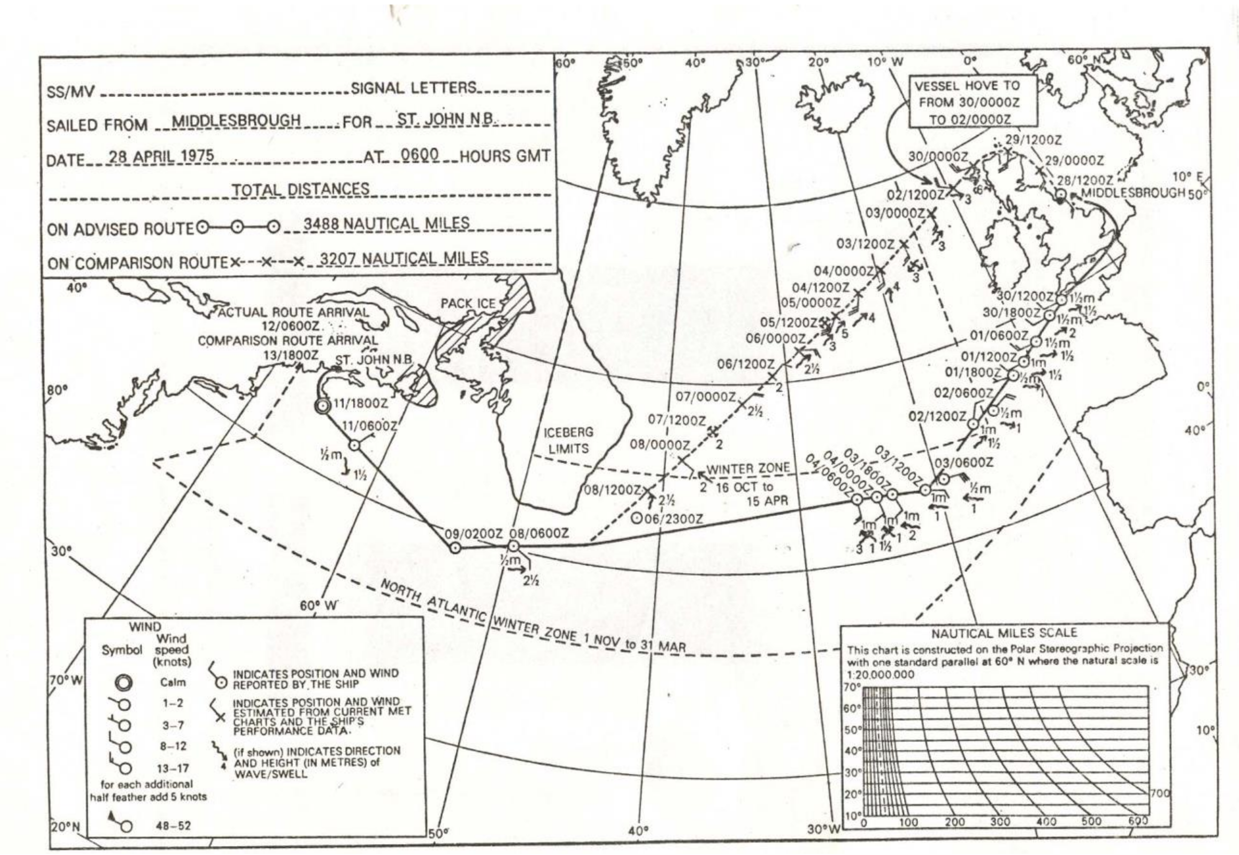
- Trim
- Observation of waves (average height and direction)
- Speed data not reliable
- Wave periods
- Swell
- Prognostic wave periods are assumed constant

Advantages of Shore Based Routing

- Good network of observations
- High speed electronic computer
- High percentage of high speed ships
- Satellite information available on wave heights

Hindcast Charts

- On completion of voyage
- The progress of the vessel during the voyage and the actual weather conditions experienced together with alternative routes.



Questions

- What is the procedure used by a shore service to get initial route to advise a new ship?
- What are the advantages of shore based weather routeing to ship based?